APPENDIX C – POTENTIAL FOR SHARING BETWEEN IMT-2000 AND TACTICAL RADIO RELAY IN THE 1755-1850 MHZ FREQUENCY BAND

A large number of existing Department of Defense (DoD) line-of-sight (LOS) microwave (MW) systems operate in the 1755-1850 MHz frequency band. This appendix addresses the potential for interference between the International Mobile Telecommunications for the Year 2000 (IMT-2000) systems and the DoD tactical radio relay (TRR) systems.

The LOS MW systems operating in the band are too numerous to analyze individually, and some of the fixed systems do not have unique requirements limiting the systems to frequencies below 3 GHz. One class of systems with requirements constraining operations to frequencies near the 1755-1850 MHz band are the DoD TRR systems, and these systems were analyzed in the assessment.

The military services require efficient methods of exchanging large quantities of digital data throughout the battlefield. The increased use of computers, digital video, and facsimile equipment in command and control, intelligence, and logistics will generate more data in the future. The military radios are deployable, transportable, point-to-point radio systems using low-to-moderate gain antennas. The military TRR equipment uses broad beamwidth antennas for quick link setup during deployments. The movement of the lightweight, flexible masts that support the antennas or the movement of shipboard antennas preclude the use of narrowbeam type antennas. The requirements for low/moderate power levels for the transportable radios and the broad beamwidth antenna limits applicable frequency band to below 3 GHz. The primary DoD TRR systems operating in the 1755-1850 MHz band are the United States (US) Army Mobile Subscriber Equipment (MSE), Tri-Services Tactical Communications (TRI-TAC), and the Navy/Marine Corps Digital Wideband Transmission System (DWTS).

C.1 MISSION OVERVIEW

C.1.1 Mobile Subscriber Equipment

The AN/GRC-103, AN/GRC-226, and AN/GRC-245 radio sets are LOS trunk radios used to link nodes (switching centers) in the Army’s tactical telecommunications system or the Army Common User System (ACUS). These radios operate in the 1755-1850 MHz spectrum band and would be degraded by the introduction of IMT-2000 systems into the band. The ACUS is a seamless, tactical communications system that provides secure, highly reliable voice and data communications for both mobile and fixed users in a tactical environment. The ACUS operates from the front-line maneuver battalions to the theater headquarters in the rear areas. This communication network is formed in two parts; the MSE and the TRI-TAC system. The MSE system is deployed at corps-level units to maneuver battalions and the TRI-TAC system is deployed at Echelon Above Corps (corps-level units to higher headquarters). The system operates like a high capacity personal communications system with rapidly transportable base stations. A three Division corps-size deployment could deploy up to eighteen microwave links depending on the operational or exercise scenario.

From command and control traffic to intelligence imagery, logistics, medical, and morale and welfare support, MSE and TRI-TAC provide the force commanders the ability to maintain effective control over their forces. MSE and TRI-TAC are tactical systems for rapid deployment in the field. This is because headquarters units, with their signature electronic emissions, are targeted for artillery and missile attacks by the enemy. The ability to set up a link to higher headquarters and subordinate units and then take down the link and move is key to the survivability of the headquarters and supports the concept of maneuver warfare. The microwave radio equipment and antennas are transportable and robust for field conditions. To maintain the operator’s capability to quickly establish a tactical microwave link, continuous field training is required.

ACUS/MSE is planned for use by the US Joint Forces Command (USJFCOM) to support Joint Task Force Civil Support (JTF-CS) in the event of a Weapons of Mass Destruction (WMD) incident. JTF-CS is tasked to provide support to a Designated Lead Federal Agency in the conduct of consequence management operations in response to a Chemical, Biological, Radiological, Nuclear and High Yield Explosives (CBRNE) incident or accident in the Continental United States (CONUS), Alaska, Hawaii, US territories and possessions.

Additionally, ACUS/MSE is used for other contingency operations within the US to include disaster relief, national emergencies, and other DoD support requirements to civil authorities, as directed from the National Command Authority.

C.1.2 Digital Wideband Transmission System

The Navy/Marine Corps DWTS provides a backbone digital communications capability, supporting amphibious operations and ground combat operations. The system supports command, control, and data transfer from the Marine Expeditionary Force (MEF) level down to the regimental level. The AN/MRC-142 is the Marine Corps element of this radio system, providing the digital backbone services (voice, video and data). This link is the only transmission media available to the Marine Corps with sufficient bandwidth to carry large quantities of critical data such as maps, overlays, intelligence pictures, and other data to the battlefield commanders. From command and control traffic to intelligence imagery, logistics, medical, and morale and welfare support, DWTS provides the force commanders the ability to maintain effective control over their forces. DWTS is a tactical systems designed to set up in the field quickly, similar to the Army's ACUS. Headquarters units, with their signature electronic emissions, are targeted for artillery and missile attacks by the enemy. The ability to set up a link to higher headquarters and subordinate units and then take the link down and move is key to the survivability of the headquarters and supports the concept of maneuver warfare. The microwave radio equipment and antennas are transportable and robust for field conditions. To maintain the operator's capability to quickly establish a tactical microwave link, continuous field training is required. The Navy ship-to-shore link of DWTS is the AN/SRC-57 radio. This is essential for amphibious operations where most of the critical information flow is from the ship to the landing forces. The anticipated service life of the AN/MRC-142 extends beyond the 2010 time frame.

DWTS is a MSE equivalent system planned for use by the USJFCOM to support JTF-CS in the event of a WMD incident. JTF-CS is tasked to provide support to a designated Lead Federal Agency in the conduct of consequence management operations in response to a CBRNE incident or accident in the CONUS, Alaska, Hawaii, US and possessions (US&P).

Additionally, DWTS is used for other contingency operations within the US to include disaster relief, national emergencies, and other DoD support requirements to civil authorities, as directed from the National Command Authority.

C.2 TACTICAL RADIO RELAY SYSTEM DESCRIPTIONS

MSE. The MSE is a multi-band, tactical LOS radio system, more accurately described as a "system-of-systems," because it is composed of several components, each of which are fully operational systems. The individual components that make up the MSE are dependent upon several portions of the radio frequency spectrum (e.g., 30-88 MHz, 225-400 MHz, 1350-1850 MHz, and 14.5-15.35 GHz). The inability of any of these components to operate successfully would result in the failure of the overall system. One critical component of the MSE, the AN/GRC-226(V)2 radio, operates in the 1755-1850 MHz frequency band. It is used to connect radio access units to the node center switch of the network. Operational use plans call for 465 units per Army Corps, giving a total of 2,325 units for five Corps. The AN/GRC-226(V)2 is a digital radio that can tune to any of 4000 available channels, spaced at 125 kHz, between 1350-1850 MHz; however, due to the allocation of most of this band to other services, users rarely have access to spectrum outside of 1350-1390 MHz and 1710-1850 MHz. The AN/GRC-226(V)2 requires a 50.125-MHz minimum frequency separation between the site transmitter and receiver for a duplex link. The technical parameters of the AN/GRC-226(V)2 used in the analysis are presented in Table C-1.

Table C-1. AN/GRC-226 (V)2 Parameters (J/F 12/6102/2)

Frequency range	1350 – 1850 MHz
Transmit power	0.5 - 5 W
Emission Bandwidth (MHz)*	1.25 (-3dB), 3.5 (-20dB), 10.55 (-60dB)
Antenna gain	20 dBi (MB), 11 dBi (20-90 deg), 2 dBi (90-180 deg)
Antenna height	30 m
Receiver bandwidth (MHz)*	0.85 (-3dB), 1.6 (-20dB), 4.4 (-60dB)
Receiver noise figure	8 dB
Receiver sensitivity	-93 dBm @ BER = 10E–5 (S/N = 14 dB)
Receiver noise power	-107 dBm
Interfering signal threshold	-113 dBm
Cable losses	2.4 dB (estimated)
Waveform	2M40F9W*, 256 – 2048 kb/s MSK

*2048 kb/s is the maximum bit rate.
MB – mainbeam
MSK – minimum shift keying

TRI-TAC. The TRI-TAC system uses the AN/GRC-103(v)3 TRR unit to provide connectivity to Army Echelons Above Corps. There are over 600 of these radios in use by the Army and reserve units throughout the US. With respect to the technical assessment addressed in this appendix, the technical parameters of the AN/GRC-103(v)3 are similar to those of the AN/GRC-226. The results of the interference assessment of the AN/GRC-226 is considered to be generally applicable to the AN/GRC-103(v)3.

HCLOS. The High Capacity LOS (HCLOS) radio system is expected to eventually replace the AN/GRC-226(V)2 radios in the MSE for the ACUS. The HCLOS radio, the AN/GRC-245(V), operates in the 225-400 MHz and 1350-2690 MHz bands with increased spectral efficiency and higher data rates compared to the current radio. The AN/GRC-245(V) requires a 50.125-MHz minimum frequency separation between the site transmitter and receiver for a duplex link. The technical parameters of the AN/GRC-245(V) used in the assessment are presented in Table C-2.

Table C-2. AN/GRC-245 (V) Parameters (J/F 12/7601)

Frequency range	1350 – 2690 MHz
Transmit power	31 mW - 1.6 W
Emission Bandwidth (MHz)*	2.0 (-3dB), 2.9 (-20dB), 7.2 (-60dB)
Antenna gain	23 dBi (mainbeam)
Antenna height	30 m
Receiver bandwidth (MHz)*	6.7 (-3dB), 8.1 (-20dB), 10.0 (-60dB)
Receiver noise figure	7 dB
Receiver sensitivity*	-86 dBm @ 8192 Kb/s and BER = 10E-5
Receiver noise power*	-99 dBm
Interfering signal threshold*	-105 dBm
Cable losses	4 dB @ 1850 MHz
Waveform	2M50W1D*,320-8256 kb/s, 32 TCM, rate 4/5 code

*8256 kb/s is the maximum bit rate.
TCM – trellis coded modulation

DWTS. The DWTS is a LOS tactical radio system providing point-to-point (shore based AN/MRC-142), ship-to-ship (ship based AN/SRC-57) and ship-to-shore (AN/SRC-57 and AN/MRC-142 or the Army AN/GRC-226) communications. The DWTS provides communications vital to the Commander Joint Task Force (CJTF), Commander Amphibious Task Force (CATF), Commander Landing Force (CLF), Amphibious Forces afloat, and US Forces ashore. The system provides afloat and ashore commanders with entry into the Global Command and Control System – Maritime (GCCS-M) to ensure common access to intelligence, mapping, order of battle, and logistics information. The DWTS provides data transmissions for Battlegroup (BG) planning, video tele-conferences, BG e-mail connectivity, Internet connectivity and intra-BG telephone connectivity. DWTS provides tactical digital wideband transmissions for voice, video, and data to support landing force command elements to include Marine regiment or Expeditionary Unit and higher and Army brigade and higher. The DWTS consists of two components, the shore based USMC AN/MRC-142 and the ship based US Navy AN/SRC-57.

AN/MRC-142. The shore based component of the DWTS, the AN/MRC-142, typically uses the frequency bands 1350-1390 MHz, 1432-1435 MHz, and 1710-1850 MHz. In addition, the AN/MRC-142 ship-to-shore links have further frequency restrictions caused by ship-based interference to the AN/SRC-57 located on ships. The AN/MRC-142 requires a 63-MHz minimum frequency separation between the site transmitter and receiver for a duplex link. The technical parameters of the AN/MRC-142 used in the evaluation are presented in Table C-3.

Table C-3. AN/MRC-142 Parameters (J/F 12/6461)

Frequency range	1350 – 1850 MHz
Transmit power	3.0 W
Emission Bandwidth (MHz)	0.4 (-3dB), 1.05 (-20dB), 3.15 (-60dB)
Antenna gain	20 dBi (mainbeam), 6.3 dBi (26 deg)
Antenna height	30 m
Receiver bandwidth (MHz)	0.8 (-3dB), 1.0 (-40 dB), 4.4 (-60 dB)
Receiver noise figure	8 dB
Receiver sensitivity	-93 dBm BER = 10E-4
Receiver noise power	-107 dBm
Interfering signal threshold	-113 dBm
Waveform	610K0F7W, 576kb/s FSK
FSK – frequency shift keying	

AN/SRC-57. The ship-based AN/SRC-57 uses an omnidirectional antenna to communicate with other ships and shore-based radios. The AN/SRC-57 can tune over the 1350-1850 MHz frequency band for operations in international waters. However, the AN/SRC-57 was granted stage four spectrum certification to operate in the bands of 1350-1390 MHz and 1755-1850 MHz within the US&P. The AN/SRC-57 can experience shipboard interference interactions that could eliminate additional frequency bands. The AN/SRC-57 can receive interference from shipboard systems such as the Target Acquisition System (TAS) MK 23 radar, AN/SPS-49 radar, and International Maritime

Satellite (INMARSAT) and can cause interference to Global Positioning System (GPS), INMARSAT, and AN/SMQ-11 Weather Satellite receivers.

The AN/SRC-57 requires a 50-MHz minimum frequency separation between the site transmitter and receiver for ship-to-ship duplex links; however, ship-to-shore links must conform to the 63 MHz separation requirements of the AN/MRC-142. The technical parameters of the AN/SRC-57 used in the assessment are presented in Table C-4.

Table C-4. AN/SRC-57 Parameters (J/F 12/7652)

Frequency range	1350 – 1850 MHz
Transmit power	5 – 250 W
Emission Bandwidth (MHz)	1.0 (-3dB), 3.0 (-20 dB), 8.0 (-60 dB)
Antenna gain	1.5 dBi Omni
Antenna height	30 m
Receiver bandwidth (MHz)	1.6 (-3 dB), 4.0 (-20 dB), 9.2 (-60 dB)
Receiver noise figure	7 dB
Receiver sensitivity	-84 dBm BER = 10E-5
Receiver noise power	-105 dBm
Interfering signal threshold	-111 dBm
Waveform	2M85F7D, 144-2304 kb/s binary FSK

C.3 COST ISSUES

There are two major equipment types in this category, the Army's MSE and TRI-TAC, and the Navy/Marine Corps DWTS. Both of these systems rely on the 1755-1850 MHz band to provide the high-end frequency component of their full-duplex channel pairs. Although both equipment sets tune over an extended frequency range, loss of this particular band would significantly reduce the number of radios which could be netted together during training exercises due to non availability of alternate bands to provide the high-end frequency component of the duplex channel. The Army has already encountered this problem with their MSE and TRI-TAC systems in Europe. To alleviate the problem, they have begun the acquisition and fielding of a new generation of radio called High Capacity Line of Sight (HCLOS) or AN/GRC-245. HCLOS tunes over an even wider range than baseline MSE and TRI-TAC, and offers the potential to mitigate the IMT-2000 third-generartion (3G) problem as well. Similar to the combat aircraft training systems, the HCLOS mitigation strategy assumes that the wider tuning range will cover some new bands that can be used by the Army to setup MSE and TRI-TAC radio links. If no such bands are provided this proposed solution is not viable. DoD's mitigation strategy for the Army's MSE and TRI-TAC equipment calls for accelerating the procurement of HCLOS considerably over the baseline program DoD currently has in place. As per the cost reimbursement rules defined in NTIA's Notice of Proposed Rulemaking (NPRM), the difference in the accelerated budget requirements over and above the baseline requirements are reimbursable and so are included in the cost estimate for IMT-2000. The same MSE and TRI-TAC program plan would be implemented under either band segmentation option, band sharing, or if access to the band was lost completely. The same plan would also be implemented regardless of the 3G introduction date.

The DoD plan for mitigating the effect of the Navy/Marine Corps DWTS system on IMT-2000 is slightly more complex than the strategy for the Army's MSE. The Navy/Marine Corps rely heavily upon these links for point to point land communications and the ship to shore links. Therefore, each option (band sharing, segmentation, band loss) must be viewed independently and with reference to operational considerations and cost. The band sharing option would require the Marine Corps to operate using fixed locations and antenna orientations or power constraints, all of which are inconsistent with the Marine Corps operational doctrine for maneuver warfare. In the event of segmentation or band loss, the Marine Corps envisions replacing the existing MRC-142 with either a modified non-developmental item (NDI) (possibly a HCLOS-like) system or a new development system based on the newly assigned spectrum. Note: Since HCLOS was never designed to work with DWTS, it would require non-recurring integration effort. Tables C-5 and C-6 present reimbursement cost data.

Table C-5. Mobile Subscriber Equipment (HCLOS) Reimbursement Cost (TY$M)

	FY02	FY03	FY04	FY05	FY06	FY07	To Complete	Total
HCLOS Acceleration	**40.1**	**49.0**	**48.7**	**11.6**	**0.0**	**0.0**	**0.0**	**149.5**

Table C-6. Digital Wideband Transmission System Reimbursement Cost (TY$M)

DWTS Band Segmentation Options Reimbursement Cost (TY$M)								
	FY02	**FY03**	**FY04**	**FY05**	**FY06**	**FY07**	**To Complete**	**Total**
Marine Corps	9.9	5.1	50.6	53.6	65.6	65.6	270.0	520.4
Navy	4.0	5.0	1.5	0.5	0.5	0.5	7.0	19.0
Total	**13.9**	**10.1**	**52.1**	**54.1**	**66.1**	**66.1**	**277.0**	**539.4**
DWTS Band Vacation Option Reimbursement Cost (TY$M)								
	FY02	**FY03**	**FY04**	**FY05**	**FY06**	**FY07**	**To Complete**	**Total**
Marine Corps	10.0	15.0	15.0	55.6	53.6	65.6	320.6	535.4
Navy	5.4	6.7	11.5	10.7	10.7	10.7	9.8	65.5
Total	**15.4**	**21.7**	**26.5**	**66.3**	**64.3**	**76.3**	**330.4**	**600.9**
DWTS Band Sharing Option Reimbursement Cost (TY$M)								
	FY02	**FY03**	**FY04**	**FY05**	**FY06**	**FY07**	**To Complete**	**Total**
Marine Corps	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Navy	5.4	6.7	11.5	10.7	10.7	10.7	7.0	62.7
Total	**5.4**	**6.7**	**11.5**	**10.7**	**10.7**	**10.7**	**7.0**	**62.7**

C.4 OPTION 1 – FULL BAND SHARING

C.4.1 Technical Assessment

The DoD TRR systems potential for sharing the 1755-1850 MHz frequency band with the IMT-2000 systems was investigated on a one-to-one basis. A distance separation required to protect each of four radio relay systems from each of the four candidate IMT-2000 systems and each of the four candidate IMT-2000 systems from the four radio relay systems was determined. The IMT-2000 mobiles and base stations (including main-beam and side-lobe antenna gains) were analyzed versus the radio relay main-beam and side-lobe antenna gains. The ship-based DWTS uses an omnidirectional antenna, and the DWTS was analyzed at the highest and lowest transmitter power setting.

The technical parameters for the tactical radios (see the *System Description* section) were obtained from the Spectrum Certification Applications and from data provided by the program manager for each radio. The technical parameters for the IMT-2000 radios used in the sharing assessment are presented in a previous section of this report. The interference threshold values of the IMT-2000 code division multiple access (CDMA) system receivers are referenced to the data rate of the CDMA modulation. The interference threshold referenced to the receiver bandwidth would be increased by the ratio of the receiver bandwidth to the data rate. The revised interference thresholds (I_t) are presented in Table C-7.

Table C-7. CDMA-2000 Receiver Interference Thresholds

	CDMA-2000 Narrowband (NB) (1.25 MHz)		CDMA-2000 Wideband (WB) (3.75 MHz)	
	Base	Mobile	Base	Mobile
Interference Threshold 1	-114.6 dBm	-110.6 dBm	-109.9 dBm	-105.9 dBm
Interference Threshold 2	-99.1 dBm	-95.1 dBm	-94.4 dBm	-90.4 dBm

The interference thresholds for the DoD tactical radio receivers were based on the Recommendation ITU-R F.1334, which limits the degradation due to interference in the fixed service receiver to 1 dB. This value corresponds to an allowed interference-to-noise power ratio (I/N) of –6 dB. Also, for one example, an additional, higher threshold was used, assuming a desired signal level of –75 dBm, and an signal-to-interference plus noise ratio (S/(I+N)) of 14 dB.

The analysis was performed to identify the required distance separation to protect the TRR receivers from the IMT-2000 transmitters and the IMT-2000 receivers from the TRR transmitters. The required propagation loss was calculated using transmitter powers, transmitter and receiver antenna gains, frequency-dependent rejection, and the receiver interference threshold as follows:

$$L_P = P_T + G_T + G_R + L_S - FDR - I_T \tag{C-1}$$

where:

L_P	=	required propagation path loss to preclude interference (dB)
P_T	=	output power of the source transmitter (dBm)
G_T	=	source transmit antenna gain in the direction of the victim receiver (dBi)
G_R	=	victim receive antenna gain in the direction of the source transmitter (dBi)
L_S	=	transmitter and receiver line losses (dB)
FDR	=	frequency-dependent rejection (dB)
I_T	=	receiver interference threshold (dBm).

The Spherical Earth Model (SEM) was used to determine the required distance separation to preclude interference. The SEM is applicable to paths over a smooth, spherical, homogenous, and imperfectly conducting earth. The dominant mode of propagation can be either LOS, diffraction, or tropospheric forward-scatter. The SEM calculates the required distance separation based on the required propagation loss, link frequency, and transmitter/receiver antenna heights.

The above assessment was used to evaluate the frequency separation versus distance separation requirements for one sample case of the AN/GRC-226 and the CDMA WB (3.75 MHz). The receiver selectivity and the transmitter emission spectrum were off-tuned, and the FDR was determined for several values of frequency separation.

C.4.2 Results

The IMT-2000 to TRR distance separation requirements are presented in Table C-8, the TRR to IMT-2000 (minimum interference threshold) distance requirements are presented in Table C-9, and the TRR to IMT-2000 (more typical interference threshold) distance separation requirements are presented in Table C-10.

For the minimum interference threshold case, the distance separation requirements between the TRR and the IMT-2000 base stations would be approximately 92 km if random antenna orientations were allowed for both systems. With the same interference threshold, the distance separation requirements between the TRR and the IMT-2000 base stations would be approximately 55 km if side-lobe antenna orientations were constrained for each system toward the other system (assumes low-power operation for the AN/SRC-57).

With the minimum interference threshold, the distance separation requirements between the TRR and the IMT-2000 mobiles would be approximately 38 km, if random antenna orientations were allowed for the TRR. If TRR main-beam antenna orientations (assumes low-power operation for the AN/SRC-57) were constrained away from areas of IMT-2000 operations and IMT-2000 mobiles were restricted from some areas of operations, the distance separation requirements would be approximately 23 km. The above distance separation requirements cannot be accommodated in many areas of TRR operations in the US.

Table C-8. IMT-2000 to Tactical Radio Relay Distance Separation Requirements Co-Channel Operation

Interference Path		CDMA NB	CDMA WB	IS-136	GSM
Source	**Victim**	**Distance (Km)**	**Distance (Km)**	**Distance (Km)**	**Distance (Km)**
IMT-2000 Base	**GRC-226 MB**	87.1	78.1	91.9	91.1
IMT-2000 Base	**GRC-226 SL**	63.9	60.7	65.5	65.2
IMT-2000 Base SL	**GRC-226 SL**	52.3	49.0	53.9	53.7
IMT-2000 Mobile	**GRC-226 MB**	22.5	19.8	23.8	23.6
IMT-2000 Mobile	**GRC-226 SL**	11	9.2	11.9	11.8
IMT-2000 Base	**GRC-245 MB**	75.2	74.7	75.5	75.5
IMT-2000 Base	**GRC-245 SL**	56.8	56.5	57.0	57.0
IMT-2000 Base SL	**GRC-245 SL**	45.0	44.6	45.1	45.1
IMT-2000 Mobile	**GRC-245 MB**	18.8	18.5	19.0	19
IMT-2000 Mobile	**GRC-245 SL**	7.4	7.2	7.5	7.5
IMT-2000 Base	**MRC-142 MB**	85.5	75.7	91.9	91.1
IMT-2000 Base	**MRC-142 SL**	63.4	59.8	65.5	65.2
IMT-2000 Base SL	**MRC-142 SL**	51.8	48.0	53.9	53.7
IMT-2000 Mobile	**MRC-142 MB**	22.0	19.0	23.8	23.6
IMT-2000 Mobile	**MRC-142 SL**	10.7	8.7	11.9	11.8
IMT-2000 Base	**SRC-57**	62.0	59.0	63.3	63.1
IMT-2000 Base SL	**SRC-57**	50.3	47.2	51.7	51.5
IMT-2000 Mobile	**SRC-57**	10	8.4	10.6	10.5

Table C-9. Tactical Radio Relay to IMT-2000 Distance Separation Requirements Co-Channel Operation

Minimum Interference Threshold

Interference Path		CDMA NB	CDMA WB	IS-136	GSM
Source	**Victim***	**Distance (Km)**	**Distance (Km)**	**Distance (Km)**	**Distance (Km)**
GRC-226 MB	**IMT-2000 Base**	82	75.4	85.0	84.2
GRC-226 SL	**IMT-2000 Base**	62.2	59.6	63.2	62.9
GRC-226 SL	**IMT-2000 Base SL**	50.5	47.9	51.6	51.3
GRC-226 MB	**IMT-2000 Mobile**	34	31.5	35.0	34.7
GRC-226 SL	**IMT-2000 Mobile**	19.5	17.5	20.4	20.2
GRC-245 MB	**IMT-2000 Base**	73.7	71.9	75.2	74.1
GRC-245 SL	**IMT-2000 Base**	55.4	53.5	56.1	55.9
GRC-245 SL	**IMT-2000 Base SL**	43.5	41.6	44.3	44.1
GRC-245 MB	**IMT-2000 Mobile**	30.0	28.3	30.7	30.5
GRC-245 SL	**IMT-2000 Mobile**	14.5	13.3	15.0	14.9
MRC-142 MB	**IMT-2000 Base**	81.3	73.6	91.4	90.5
MRC-142 SL	**IMT-2000 Base**	61.9	58	65.6	65
MRC-142 SL	**IMT-2000 Base SL**	50.2	46.2	54.1	53.5
MRC-142 MB	**IMT-2000 Mobile**	33.7	29.9	37.4	36.8
MRC-142 SL	**IMT-2000 Mobile**	19.4	16.3	22.5	21.9
SRC-57 HP	**IMT-2000 Base**	79.8	74.0	83.5	82.7
SRC-57 LP	**IMT-2000 Base**	62.2	59.3	63.6	63.3
SRC-57 HP	**IMT-2000 Base SL**	65.7	62.9	67.0	66.8
SRC-57 LP	**IMT-2000 Base SL**	50.6	47.6	52.0	51.7
SRC-57 HP	**IMT-2000 Mobile**	33.2	30.3	34.5	34.2
SRC-57 LP	**IMT-2000 Mobile**	19.6	17.3	20.7	20.5

*Desired signal at sensitivity, I/N = - 6 dB

Table C-10. Tactical Radio Relay to IMT-2000 Distance Separation Requirements Co-Channel Operation

Typical Interference Threshold

Interference Path		CDMA NB	CDMA WB	IS-136	GSM
Source	**Victim***	**Distance (Km)**	**Distance (Km)**	**Distance (Km)**	**Distance (Km)**
GRC-226 MB	**IMT-2000 Base**	64.3	61.8	65.4	65.1
GRC-226 SL	**IMT-2000 Base**	48.2	45.6	49.3	49.0
GRC-226 SL	**IMT-2000 Base SL**	36.2	33.6	37.4	37.1
GRC-226 MB	**IMT-2000 Mobile**	21.3	19.2	22.2	22.0
GRC-226 SL	**IMT-2000 Mobile**	10.2	8.9	10.8	10.7
GRC-245 MB	**IMT-2000 Base**	60.3	58.4	61.0	60.8
GRC-245 SL	**IMT-2000 Base**	41.2	39.3	42.0	41.8
GRC-245 SL	**IMT-2000 Base SL**	29.3	27.4	30.0	29.8
GRC-245 MB	**IMT-2000 Mobile**	18.1	16.7	18.6	18.5
GRC-245 SL	**IMT-2000 Mobile**	7.0	6.2	7.3	7.2
MRC-142 MB	**IMT-2000 Base**	64.1	60.2	67.8	67.2
MRC-142 SL	**IMT-2000 Base**	47.9	43.9	51.8	51.2
MRC-142 SL	**IMT-2000 Base SL**	36.0	31.9	39.9	39.3
MRC-142 MB	**IMT-2000 Mobile**	21.1	18.0	24.4	23.8
MRC-142 SL	**IMT-2000 Mobile**	10.1	8.1	12.3	11.9
SRC-57 HP	**IMT-2000 Base**	63.6	60.7	64.9	64.6
SRC-57 LP	**IMT-2000 Base**	48.3	45.3	49.7	49.4
SRC-57 HP	**IMT-2000 Base SL**	52.0	48.9	53.3	53.0
SRC-57 LP	**IMT-2000 Base SL**	36.3	33.3	37.7	37.5
SRC-57 HP	**IMT-2000 Mobile**	20.7	18.3	21.8	21.6
SRC-57 LP	**IMT-2000 Mobile**	10.3	8.7	11.0	10.9

*Desired Signal 10 dB above sensitivity and BER = 10E-3

For one example interaction, the distance separation requirements were also determined for the case of a TRR link with a typical received signal level. The example uses CDMA WB (3.75 MHz) interference to an AN/GRC-226 receiver. The AN/GRC-226 link with an elevated site location and favorable weather parameters could receive a faded desired signal level of -75 dBm with a corresponding interference threshold of -89 dBm, for an S/(I+N) = 14 dB. The required distance separation values for this example are presented in Table C-11.

If an interference threshold for a typical received signal level (approximately 10 dB above receiver sensitivity for the IMT-2000 or -75 dBm for the AN/GRC-226) is used, the separation requirements are 68 km and 40 km for random antenna orientations (mainbeam) and sidelobe antenna orientations, respectively. These less conservative separation distances would still be difficult to implement at most TRR operations areas.

Table C-11. CDMA-2000 NB (1.25 MHz) to AN/GRC-226 Co-Channel Operation

Interference Path		Source Transmitter Data			Victim Receiver Data			FDR	Path Loss	Distance
Source	Victim	Power	Antenna	TX Cable	Int Thresh	Antenna	RX Cable			SEM
		dBm	dBi	dB	dBm	dBi	dB	dB	dB	Km
CDMA NB Base	GRC-226 MB	40	15	1	-89	20	2.4	1.8	158.8	58.6
CDMA NB Base	GRC-226 SL	40	15	1	-89	2	2.4	1.8	140.8	42.2
CDMA NB Base SL	GRC-226 SL	40	2	1	-89	2	2.4	1.8	127.8	30.3
CDMA NB Mobile	GRC-226 MB	20	0	0	-89	20	2.4	1.8	124.8	8.2
CDMA NB Mobile	GRC-226 SL	20	0	0	-89	2	2.4	1.8	106.8	3.0

The frequency separation verses distance separation requirements for one sample case of the AN/GRC-226 and the CDMA WB (3.75 MHz) are presented in Table C-12. The frequency separation was limited to 5 MHz because data was not available on the IMT-2000 systems that are under development. These preliminary calculations indicate that separation distances of 34.5 km are required for one channel separation (5MHz) between the AN/GRC-226 and the CDMA WB (3.75 MHz) base station.

Table C-12. Frequency Vs. Distance Separation Requirements for the AN/GRC-226 and the CDMA-2000 WB (3.75 MHz)

Interference Path		Off-tuning	Separation Distance
Source	Victim	MHz	Km
AN/GRC-226 MB	CDMA WB Base	0	75.3
		1.0	75.3
		2.0	70.6
		3.0	58.3
		4.0	45.6
		5.0	34.5
CDMA WB Base	AN/GRC-226 MB	0	78.1
		1.0	75.3
		2.0	69.9
		3.0	55.7
		4.0	20.5
		5.0	16.4

C.4.3 Operational Impact

C.4.3.1 Mobile Subscriber Equipment

For the 2003 time frame, the Army must continue to operate MSE and TRI-TAC in the 1755-1850 MHz band for battlefield training. Accommodating 3G systems in the 1755-1850 MHz band will compound the difficulties the Army experiences today. Restricting transmitter/receiver locations and antenna-pointing directions will limit realistic training of units and will limit the commanders' ability to realistically deploy signal assets. Not setting up links in exercise scenario dependent locations, but instead setting them up in pre-planned, pre-coordinated sites exercise after exercise, reduces the microwave operator's combat skills. The learning curve for setting up the links in actual deployment situations will be steeper and longer because of the lack of realistic field exercise training. The time required to get effective command and control established, especially in the information intensive battleground today, can be a deciding combat factor. Because of this, realistic training operations for microwave systems must continue.

US Army Guard and Reserve units are deploying at a greater pace, and keeping their training current is vital. Guard and Reserve component units with ACUS/MSE and TRI-TAC systems may be severely restricted in training opportunities because of their proximity to IMT-2000 base stations/mobile phone concentrations. There are 10 Army National Guard Division Signal Battalions with MSE AND TRI-TAC located throughout the US and a number of Army Reserve Signal units (companies, battalions, brigades, commands) with ACUS/TRI-TAC systems using the AN/GRC-103 (V)4 radio. Army Reserve Air Defense units in the also use the AN/GRC-103 (V)4 radio. If these units are restricted from training operations at home locations, then the units must deploy to the nearest training area, thereby imposing significant cost on training that can be accomplished today with relatively small investment.

If 3G is accommodated in this frequency band, and mitigation techniques are imposed on the Army ACUS, the installation Frequency Managers would need to coordinate with the IMT-2000 system operators prior to conducting training exercises to determine acceptable frequencies for use. At bases near population centers, this will be difficult because of the large separation distances required to preclude interference under co-frequency operation and because of how ACUS is deployed. The frequency managers at Ft Hood, TX, Ft Bragg, NC, and the National Training Center at Ft Irwin, CA, are already facing crowded frequency space and further sharing restrictions will make any large-scale exercises unworkable. Restricting the size of exercises could reduce the radiation problem but could preclude full scale training exercises. If IMT-2000 systems are deployed in significant numbers around the base, the only choice is to reduce the size and scope of training exercises—directly affecting military readiness.

For 2006 and 2010, the operational impact to US forces, if IMT-2000 systems begin operation in the 1755-1850 MHz band, are the same as 2003, unless access to additional spectrum in bands up to 2690 MHz is provided on a primary basis with equivalent regulatory protection. As HCLOS radios replace the current generation of MSE and TRI-TAC equipment, additional flexibility in frequency selection could reduce, but not eliminate, the impact resulting from loss of the 1755-1850 MHz band.

C.4.3.2 Digital Wideband Transmission System

The option for full band sharing is extremely difficult, as described previously in the section on ACUS/MSE. The Navy/Marine Corps depend on the DWTS for information transfer between ships and troops ashore as well as dissemination throughout the battlefield. There are no replacement radios planned for the DWTS, so continued access to the 1755-1850 MHz band is crucial to amphibious operations training. Marine Corps training/warfare doctrine is based on maneuver warfare. The ability of the Fleet Marine Force and its commanders to effectively train troops would be severely degraded if restrictions on flexibility were imposed to allow 3G systems to operate in the same band as DWTS.

By restricting the location of transmitters and receivers, restricting the direction in which antennas can be pointed, limiting link lengths, or limiting transmitter power levels, the Marine Corps capability for training maneuver warfare and command and control is greatly reduced. The whole premise behind maneuver warfare is rapid movement and quick-strike engagement of the enemy. The communications network must remain as mobile as the rest of the command and control elements. The Marine Corps would immediately lose the capability to train Marines as they would fight.

DWTS also serves as the link between Navy amphibious support ships and the Marine Corps troop ashore. Restrictions on transmitter power, antenna pointing angles, link lengths, and other factors would reduce or eliminate the utility of this vital link. Ship movement requires broad beamwidth antennas for the shore system so that communications can be maintained while the ship retains freedom of movement for self-protection.

Limiting the size of exercises severely restricts the utility of training activities. If the Marine Corps could no longer stage MEF/division level exercises, it would lose the ability to properly train its troops and also lose the capability to rehearse for deployments. This would reduce the readiness of our warfighters by increasing the time required to establish critical command and control links. Restricting training to certain specified ranges would also severely impact operations. This will require large troop movements to other training locations at a significant price in both cost and lost time.

This especially impacts the Reserve units, as they would no longer be able to participate in local training but would have to travel to specified training locations or ranges. Given the proximity of Camp Pendleton to San Diego and other populous areas in Southern California, the entire base may become off limits to large-scale training operations. Training at Yuma, AZ, may be curtailed as well because of its location. Training at Quantico would also be in jeopardy because of its proximity to

Northern Virginia and Washington, DC. Before long, training at Camp Lejeune would likely meet a similar fate.

As stated previously, band sharing is not an option for the Marine Corps. There is no planned replacement for the AN/MRC-142 prior to a Joint Tactical Radio System (JTRS) compliant replacement, therefore any implementation of band sharing prior to 2010 results in the inability of DWTS to support the way the Navy/Marine Corps trains and fights.

C.5 OPTION 2 – BAND SEGMENTATION/PARTIAL BAND SHARING

C.5.1 1755-1805 MHz Retained

The first band segmentation option would divide the 1755-1850 MHz band into two segments with 3G in 1710-1755 MHz and 1805-1855 MHz, and TRR in the 1755-1805 MHz band. This segmentation plan would eliminate the 1805-1850 MHz band at all DoD TRR sites and possibly eliminate 1710-1755 MHz at the 16 sites at which Federal systems are to be protected indefinitely as specified in the Omnibus Budget Reconciliation Act of 1993 (OBRA-93). The TRR are currently allocated the 1350-1390 and 1755-1850 MHz bands in CONUS and will receive protection indefinitely in the 1432-1435 and 1710-1755 MHz bands at specific sites. The TRR is currently allocated between 135 and 183 MHz of spectrum depending on the location. The Army can require access to all the spectrum in the two 1350-1390 and 1755-1850 MHz sub-bands in order to satisfy data requirements at the Corps and Division level. The US Marine Corps (USMC) has similar spectrum requirements to support Marine Expeditionary Unit exercises and a requirement for shipboard-compatible frequencies for ship-to-shore links. The spectrum lost in this option would constitute 33% to 49% of the frequencies in the 1350-1850 MHz band used for the higher data rate TRR communications networks. In addition, TRR duplex link frequency assignments would not be possible at sites without access to 1350-1435 MHz frequencies because of the requirement for a minimum of 50.125-63 MHz frequency separation between transmit and receive frequencies. Sufficient band separation between transmit and receive frequencies is required by TRR systems for acceptable operation.

2003 Time Frame. Any significant loss of access to spectrum in the band 1755-1850 MHz will have unacceptable operational impact on radio relay operations.

2006 Time Frame. The IMT-2000 system is estimated at a 50% development level in urban areas and 30% level in suburban areas. The development along interstate highways is expected to be in the same range. The two sub-bands 1710-1755 and 1805-1850 MHz could be unavailable for TRR use at this time frame. As a result, spectrum would not be available to support the number of TRR communications links required in large exercises. Any significant loss of access to spectrum in the band 1755-1850 MHz will have unacceptable operational impact on radio relay operations.

The loss of access to the 1710-1755 and 1805-1850 MHz bands in 2006 would reduce the spectrum to support TRR communications network by 33% to 49%. This loss of spectrum would have a corresponding impact on the number of communications links available to support large exercises.

The impact between the TRR and the IMT-2000 systems at the band edges is addressed by a frequency-distance separation analysis. The estimates for the IMT-2000 network in 2006 are for a 50% development in urban areas and along major interstate highways. At some TRR sites, the 1755-1805 MHz band available for the TRR would have increasing power densities at the band edges from the 3G transmitters in the surrounding bands. The frequency-distance separation requirement to preclude interference was determined for both the TRR and the IMT-2000. The frequency-distance separation requirements for CDMA-WB (spread spectrum) interference to the TRR is provided in Figure C-1, and requirements for GSM (time division multiple access (TDMA)) interference to the TRR is provided in Figure C-2. TRR interference to CDMA-WB is identified in Figure C-3, and TRR interference to GSM is identified in Figure C-4.

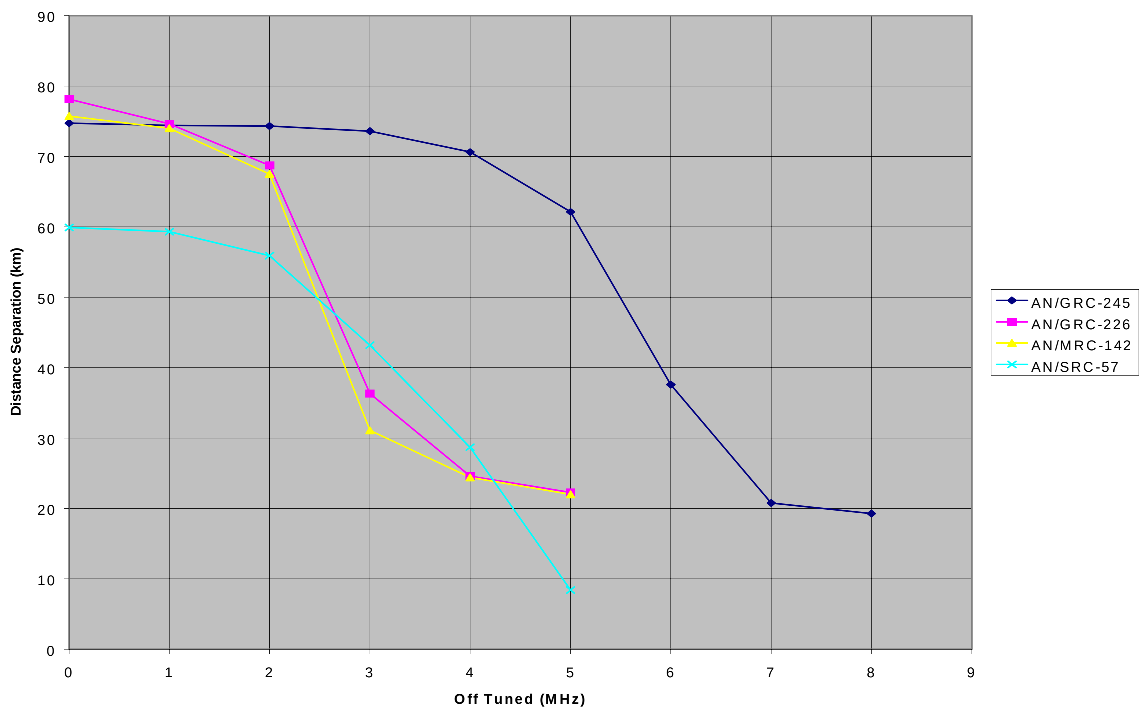

Figure C-1. Frequency-Distance Separation for CDMA-WB to TRR

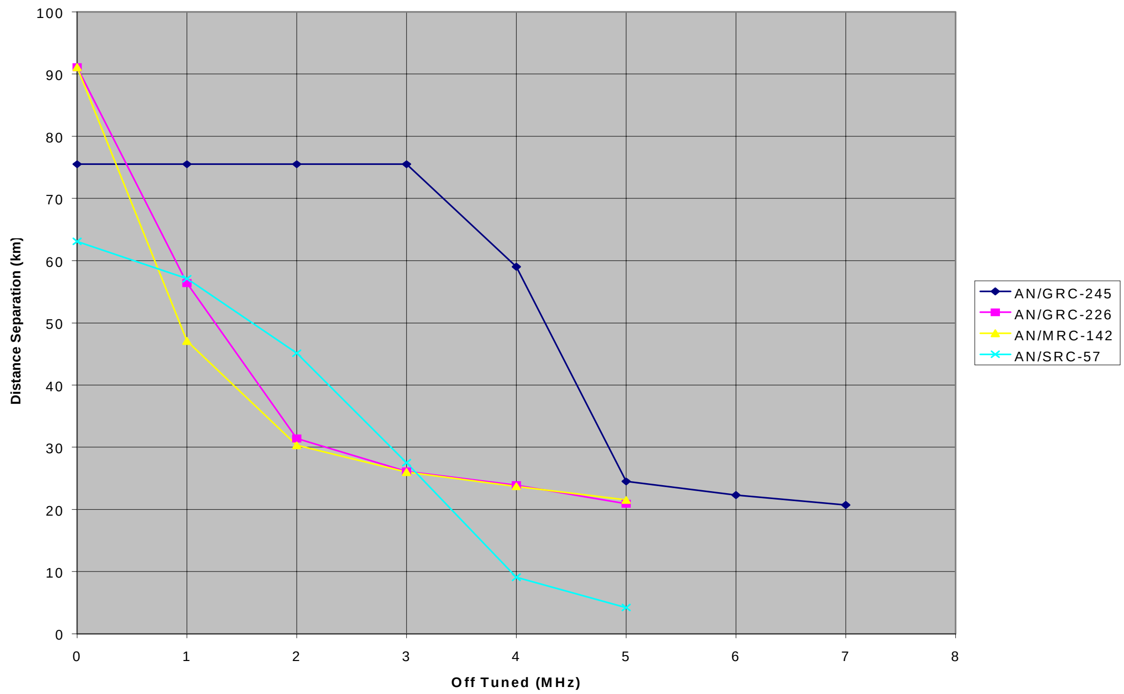

Figure C-2. Frequency-Distance Separation for IMT-2000 GSM to TRR

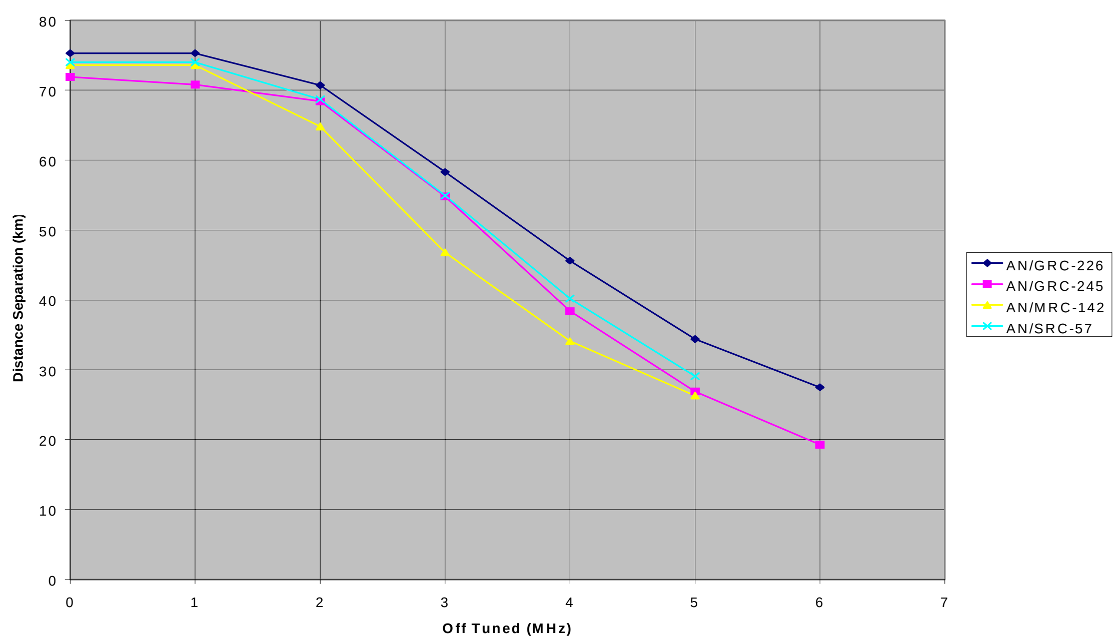

Figure C-3. Frequency-Distance Separation for TRR to CDMA-WB

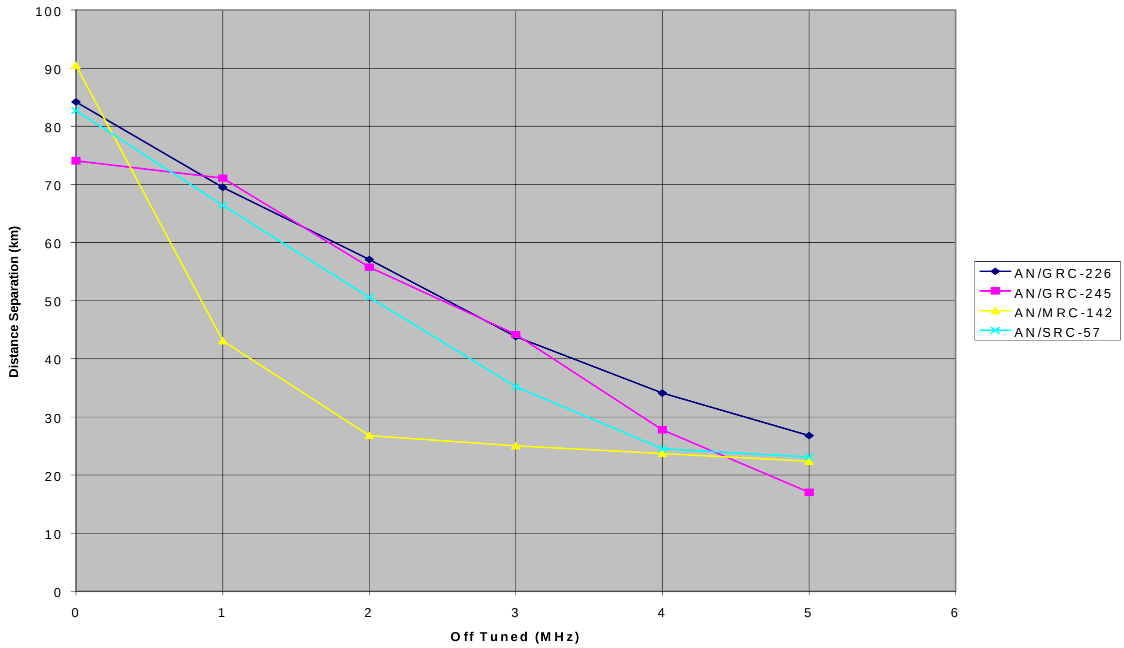

Figure C-4. Frequency-Distance Separation for TRR to GSM

The frequency-distance separation requirements in Figure C-1 to C-4 are for mainbeam antenna interactions for both the TRR and the IMT-2000 radios. The data indicates that the TRR and the IMT-2000 channel assignments at the edges of the 1755-1805 MHz would have to be controlled to avoid interference impact to the TRR and an additional loss of spectrum. For example in Figure C-1, the AN/GRC-226, AN/MRC-142 and AN/SRC-57 radios require approximately 30 km of separation with CDMA-WB base stations for frequency assignments separated by 3.75 MHz (approximately the band edge channel frequency separation) to provide compatible operations. However, the AN/GRC-245 would require 70 km of separation for band edge channels to obtain compatible operations and would have to increase the frequency separation to 6.25 MHz off tuned (approximately two channels of separation) to obtain the 30 km distance separation. The interference from the TRR transmitters to the IMT-2000 receivers in Figures C-3 and C-4 does not indicate a large difference in the separation requirement between the four TRR transmitters. In urban areas, channels on the band edges could be eliminated for TRR use if the AN/GRC-245 is assigned to the channels at the band edges.

2010 Time Frame. In the 2010 time frame, the IMT-2000 development level would be 100%, and only 1755-1805 MHz frequencies would be available for the TRR. The spectrum lost in this option would constitute 33% to 49% of the frequencies used for the higher data rate TRR communications networks. The AN/GRC-245 could experience the loss of one additional 2.5 MHz channel at each edge of the 1755-1805 MHz band at sites with high IMT-2000 traffic. In addition, TRR duplex link frequency assignments would not be possible at sites without access to 1350-1435 MHz frequencies because of the requirement for a minimum of 50.125-63 MHz frequency separation between transmit and receive frequencies.

C.5.2 Phased Segmentation to 1790-1850 MHz Retained

This band segmentation proposal would locate IMT-2000 in 1710-1790 MHz and TRR in 1790-1850 MHz. The spectrum lost in this option would constitute 26% to 44% of the frequencies in the 1350-1850 MHz band used for higher data rate tactical radio relay. The technical assessment is the same as in subsection C.5.1.

2003 Time Frame. Any significant loss of access to spectrum in the band 1755-1850 MHz will have unacceptable operational impact on radio relay operations.

2006 and 2010 Time Frame. This band segmentation proposal would locate IMT-2000 in 1710-1790 MHz and TRR in 1790-1850 MHz. The IMT-2000 frequencies are not expected to be available for TRR use in this time frame. The spectrum lost in this option would constitute 26% to 44% of the frequencies used for higher data rate tactical radio relay. The AN/GRC-245 could experience the loss of one additional 2.5 MHz channel at each edge of the 1790-1850 MHz band at sites with high IMT-2000 traffic. A limited number of duplex links would be available for the AN/GRC-226, AN/GRC-245 and AN/SRC-57 radios using only the 1790-1850 MHz band. The AN/MRC-142 radios could not obtain frequency assignments using only the 1790-1850 MHz band because of the minimum 63 MHz frequency separation between the receiver and the transmitter on duplex links.

C.5.3 Operational Impact

C.5.3.1 Mobile Subscriber Equipment

By 2003, any reduction in available spectrum would further reduce the size and scope of training exercises in training areas where frequency space is already at a premium. Fielding of HCLOS radios would not be sufficient to provide any significant relief in this time frame. Inputs to Army training would be similar to those described in Option 1, around large training areas; however, the impacts to Reserve and National Guard activities may be minimal if access in the remaining government spectrum is maintained.

For the 2006 time frame, some impact to training is still expected; however, fielding of HCLOS radios could improve the situation if access to frequencies up to 2690 MHz is provided on a primary basis with equivalent regulatory protection. By the 2010 time frame, HCLOS fielding should have replaced current generation radios and if access to frequencies up to 2690 MHz is provided, operational impacts to the Army ACUS will be minimal.

C.5.3.2 Digital Wideband Tactical System

This phased-segmentation scenario would not support the amphibious and general battlefield training requirements because of the inherent limitations as specified in Option 1. The 50 MHz of continuous frequency allocation listed in both scenarios does not allow for the requisite frequency separations needed for collocated transmit and receive operation, and access to other portions of the DWTS tuning range is already severely restricted. This would be true until a replacement radio could be developed and fielded in significant numbers, which could not be accomplished until at least the 2010 time frame.

C.6 OPTION 3 – PARTIAL BAND SEGMENTATION/COMBINATION WITH 2025-2110, 2200-2290, AND 2500-2690 MHZ BANDS

C.6.1 Technical Assessment

The first band segmentation option would divide the 1755-1850 MHz band into two segments with IMT-2000 in 1710-1755 MHz and 1805-1855 MHz, and TRR in the 1755-1805 MHz band. This segmentation plan would eliminate the 1805-1850 MHz band at all TRR sites and eliminate 1710-1755 MHz at the 16 sites at which Federal systems are to be protected indefinitely as specified in OBRA-93. The TRR are currently allocated the 1350-1390 and 1755-1850 MHz bands in CONUS and will receive protection indefinitely in the 1432-1435 and 1710-1755 MHz bands at specific sites. The TRR is currently allocated between 135 and 183 MHz of spectrum depending on the location. The spectrum lost in this option would constitute 33% to 49% of the frequencies in the 1350-1850 MHz band used for the higher data rate TRR communications networks. In addition, TRR duplex link frequency assignments would not be possible at sites without access to 1350-1435 MHz frequencies because of the requirement for a minimum of 50.125-63 MHz frequency separation between transmit and receive frequencies.

The second band segmentation proposed would locate IMT-2000 in 1710-1790 MHz and TRR in 1790-1850 MHz. The spectrum lost in this option would constitute 26% to 45% of the frequencies used for higher data rate tactical radio relay.

The spectrum lost to the TRR through one of the partial band segmentation options (between 45 and 90 MHz) could possibly be replaced by spectrum above 2000 MHz if the existing TRR are replaced by radios operating at frequencies up to 2690 MHz. The 2025-2110, 2200-2290, 2500-2690 MHz bands are evaluated for compatibility between the existing users of the band and the TRR.

2003 Time Frame. Any significant loss of access to spectrum in the band 1755-1850 MHz will have unacceptable operational impact on radio relay operations.

2006 Time Frame. The IMT-2000 system is estimated at a 50% development level by in urban areas and 30% level in suburban areas. The development along interstate highways is expected to be in the same range. The IMT-2000 frequencies are not expected to be available for TRR use in this time frame. The new TRR operating at frequencies above 2000 MHz are not expected to be available in significant numbers by 2006, which would allow for the use of frequencies above 2000 MHz. As a result, spectrum would not be available to support the number of TRR communications links required in large exercises.

The loss of access to the 1710-1755 and 1805-1850 MHz bands in 2006 would reduce the spectrum to support TRR communications network by 33% to 49%. The 1710-1790 MHz spectrum lost in the second option would eliminate 26% to 45% of the frequencies used for higher data rate tactical radio relay. This loss of spectrum would have a corresponding impact on the number of communications links available to support large exercises.

The development and fielding of new TRR operating at frequencies above 2000 MHz would not be possible before 2006. The Army has developed and received the initial procurement of the AN/GRC-245 radios that can operate from 1350-2690 MHz. The AN/GRC-245 is not expected to be procured in sufficient quantities to replace the AN/GRC-226 until near 2008. The USMC and the Navy have recently fielded the AN/MRC-142 and AN/SRC-57 DWTS radios. A replacement DWTS radio with an extended frequency range to 2690 MHz is not in development and the procurement of new radios (if technically feasible) would extend beyond the 2006 time frame.

2010 Time Frame. In the 2010 time frame the IMT-2000 development would be complete and only the 1350-1390 and 1755-1805 MHz frequency bands or the 1350-1390 and 1790-1850 MHz frequency bands would be available for TRR use. The new TRR operating at frequencies above 2 GHz could be available by 2010. If sufficient spectrum is available for operations in the higher bands, the communications requirements for large exercises could be supported. The AN/GRC-245 could experience the loss of one additional 2.5 MHz channel at each edge of the 1755-1805 MHz band at sites with high IMT-2000 traffic.

The frequency bands above 2000 MHz available for DoD operations were investigated for suitability for TRR operations. This investigation is discussed below.

C.6.1.1 2025-2110 MHz Band

The 2025-2110 MHz band is used by the non-government fixed and mobile service, specifically Electronic News Gathering (ENG) systems, by space research, by space operations (earth to space) and Earth exploration-satellite services. The band would have to be allocated with equivalent regulatory protection for government fixed and mobile services. The above incumbent systems in the band were analyzed for compatibility with the TRR.

C.6.1.1.1 Electronic News Gathering

The ENG systems are used for on-location coverage of news events or live-action video during sports and entertainment events. The transportable ENG, used by most local television stations for on-location coverage, are generally mounted in vans and operate in a stationary mode transmitting video to a fixed receive site. The total number of 2 GHz ENG systems in the US exceeds 4000. The parameters of a typical ENG system are provided in Table C-13.[1, 2]

Table C-13. Parameters of a Typical Electronic News Gathering System

Frequency range	1990-2110 MHz
Transmit power	12 W
Channel Bandwidth (MHz)	17.0
Antenna gain	22 dBi (mainbeam), 2 dBi (sidelobe)
Antenna height	15 m (Transportable), 30 m (Fixed Receive)
Receiver bandwidth (MHz)	17.0 (-3dB)
Receiver noise figure	3 dB
Receiver sensitivity	NA
Receiver noise power	-99 dBm
Interfering signal threshold	-108 dBm
Cable losses	2 dB

The interference power from the TRR to the ENG receiver was calculated using the standard received power equation. The distance separation required to reduce the TRR power to a level below the ENG interference threshold was calculated and provided in Table C-14. The reverse (ENG to TRR) interference interactions were calculated and are provided in Table C-15.

[1] W. Horne, Characteristics and Model of Electronic News Gathering Systems Operating in the 1990-2110 MHz Band, USTG 7-1/101, Greenbelt, MD: GSFC, 10 September 1993.

[2] Lloyd Apirian, et al., *EMC and Personnel Exposure Analysis of Proposed Backup GOES Earth Station*, JSC-CR-97-035, Annapolis, MD: DoD JSC, October 1997.

Table C-14. Interference Calculations TRR Transmitter to Electronic News Gathering (ENG) Receiver

2025-2110 MHz Band

Interference Path		Source Transmitter Data			Victim Receiver Data			FDR	Path Loss	Distance
Source	Victim	TX Power	TX Antenna	TX Cable**	Inter Threshold***	RX Antenna*	RX Cable			SEM
		dBm	dBi	dB	dBm	dBi	dB	dB	dB	Km
GRC-245 MB	ENG Mainbeam	32	25	4	-108	22	2	0	181.0	75.2
GRC-245 MB	ENG Sidelobe	32	25	4	-108	2	2	0	161.0	56.0
GRC-245 SL	ENG Sidelobe	32	2	4	-108	2	2	0	138.0	37.3

*ENG receive station sidelobe gain is 2 dBi, receive station antenna height is 30 meters

** Cable loss from J/F 12 for GRC-245

***Desired signal at sensitivity, I/N = - 9 dB

Table C-15. Interference Calculations For Transportable Electronic News Gathering (ENG) to TRR Receiver

2025-2110 MHz Band

Interference Path		Source Transmitter Data			Victim Receiver Data			FDR	Path Loss	Distance
Source	Victim	TX Power	TX Antenna*	TX Cable	Inter Threshold***	RX Antenna	RX Cable**			SEM
		dBm	dBi	dB	dBm	dBi	dB	dB	dB	Km
ENG Mainbeam	GRC-245 MB	40.8	22	2	-105	25	4	3.4	183.4	71.1
ENG Sidelobe	GRC-245 MB	40.8	2	2	-105	25	4	3.4	163.4	50.2
ENG Sidelobe	GRC-245 SL	40.8	2	2	-105	2	4	3.4	140.4	31.9

*ENG transmit station sidelobe gain is 2 dBi, transmit station antenna height is 15 meters

** Cable loss from J/F 12 for GRC-245

***Desired signal at sensitivity, I/N = - 6 dB

The distance separation requirement of 75.2 km between the TRR and the ENG fixed receive site would be difficult to accomplish. The ENG receive sites are typically in urban areas, but many TRR sites are within 75.2 km of urban areas. The distance separation requirements of 71.1 km between the transportable ENG transmitter and the TRR would be more difficult to meet because the transportable ENG range can extend into rural areas. Because of the distance separation requirements to avoid interference and the large number of ENG systems, band sharing would not be possible between the TRR and the ENG.

C.6.1.1.2 Space Ground Link Subsystem (SGLS) Uplink

The SGLS uplink operating in the 2025-2110 MHz band is assumed to have parameters that are the same as the 1755-1850 MHz uplink. The parameters of the SGLS uplink have been provided in the previous section. The analysis calculated the interference power from the SGLS transmitter to the TRR using the standard received power equation. Green shading identifies the regions on the figures where the SGLS interference exceeds the interference threshold of the TRR receiver.

The plots for the New Hampshire Station (NHS), the Colorado Tracking Station (CTS), the Eastern Vehicle Checkout Facility (EVCF) and the Onizuka Air Station (OAS) SGLS sites are provided in Figures C-5 to C-8, respectively.

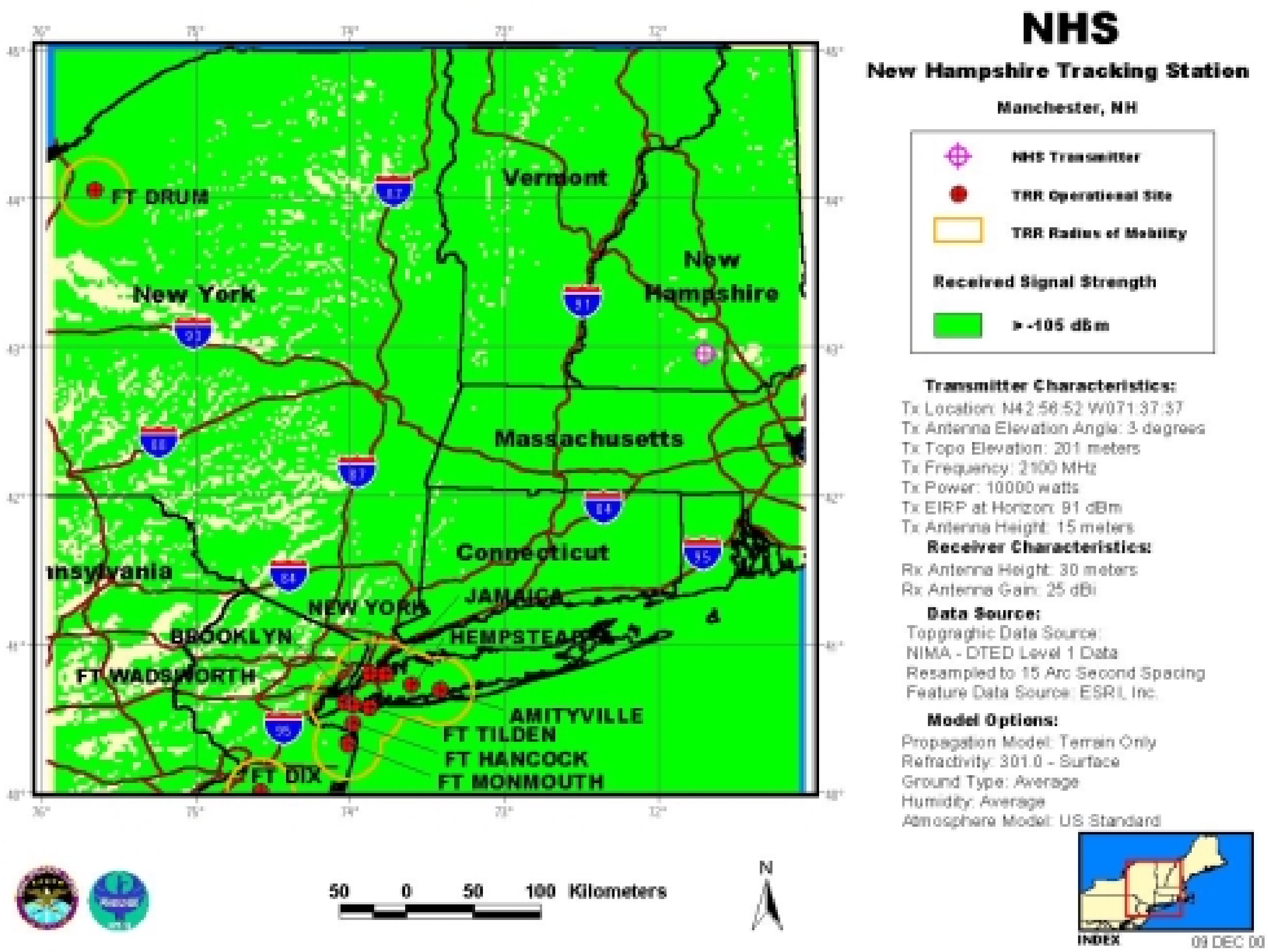

Figure C-5. Plot of NHS SGLS Interference to TRR Receivers

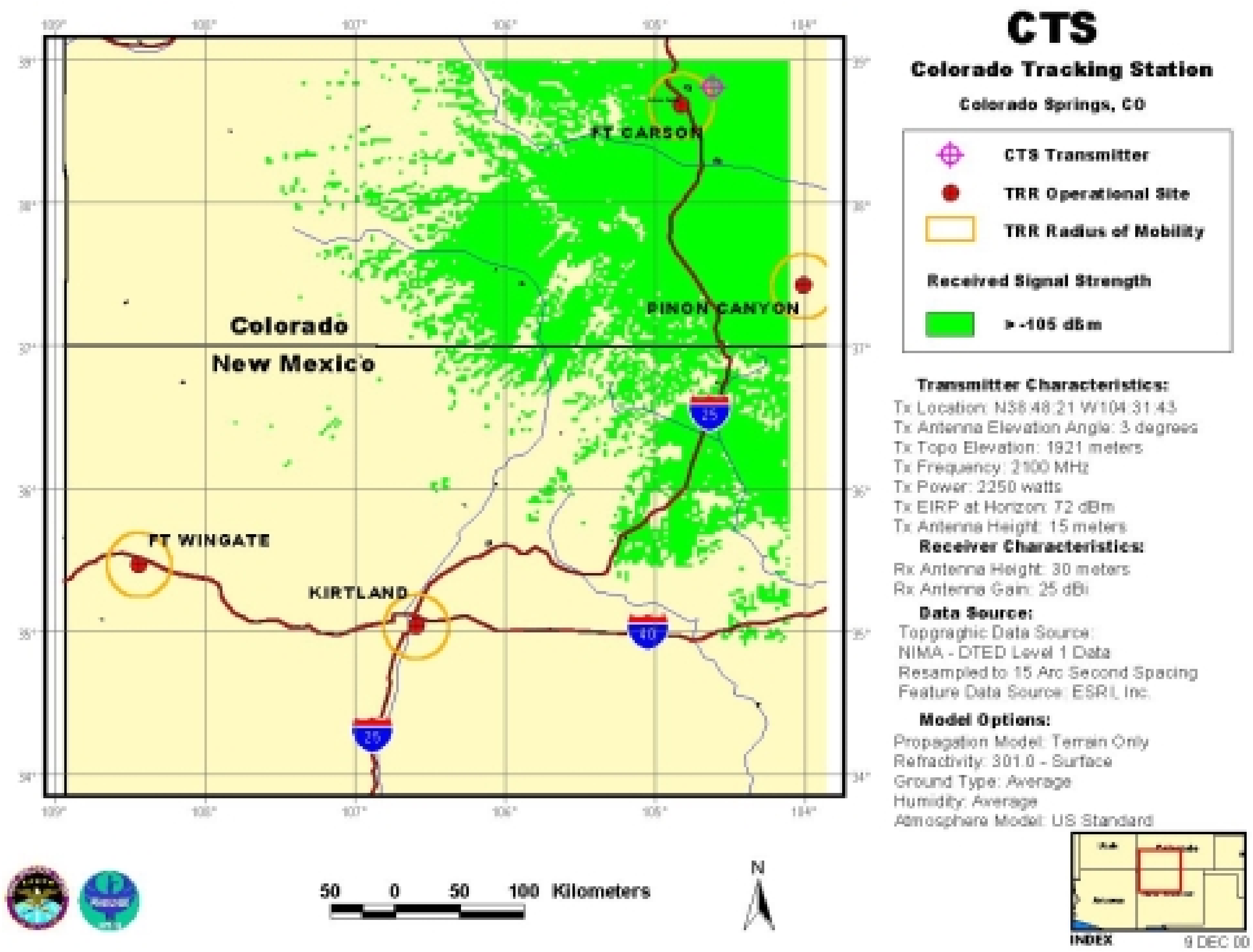

Figure C-6. Plot of CTS SGLS Interference to TRR Receivers

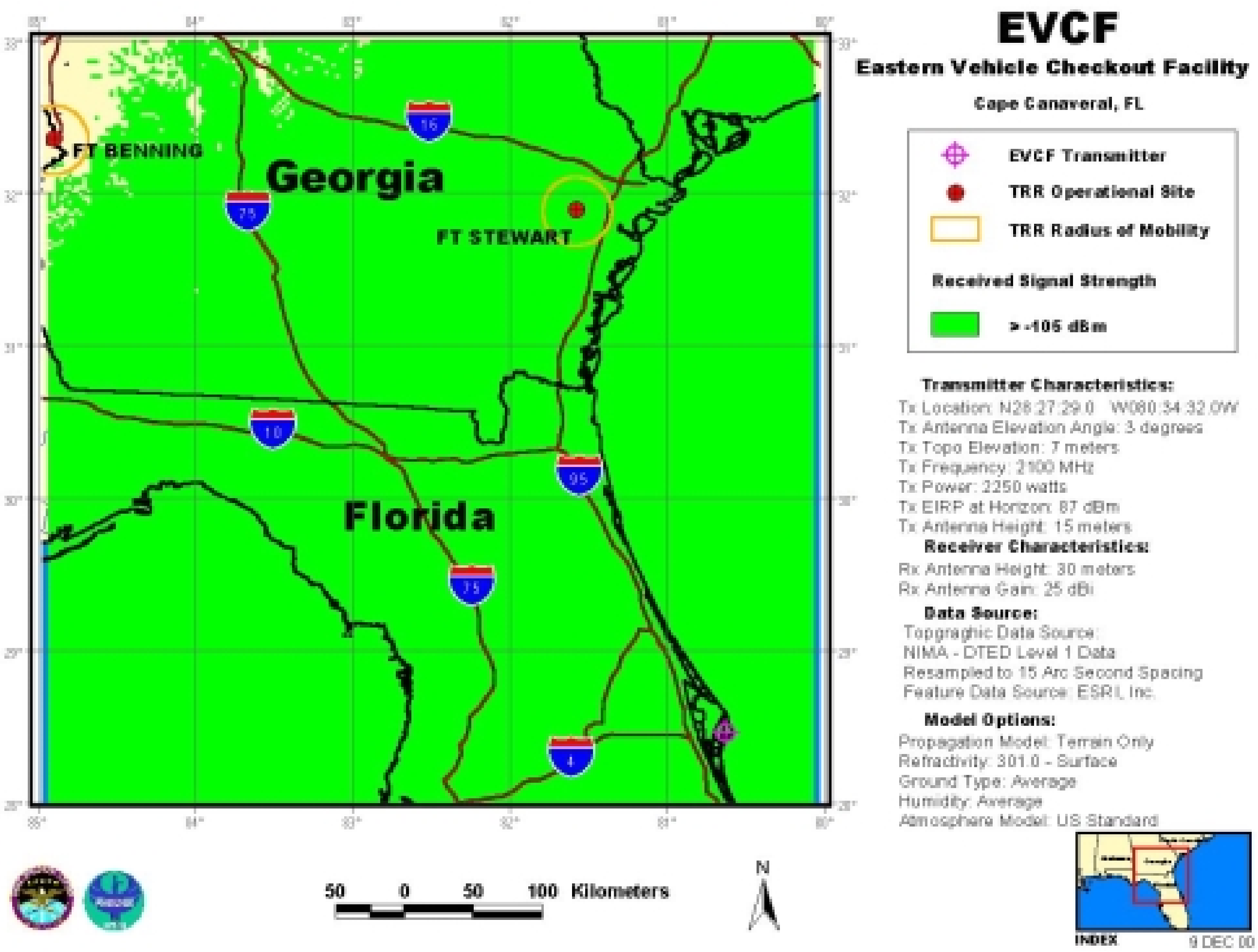

Figure C-7. Plot of EVCF SGLS Interference to TRR Receivers

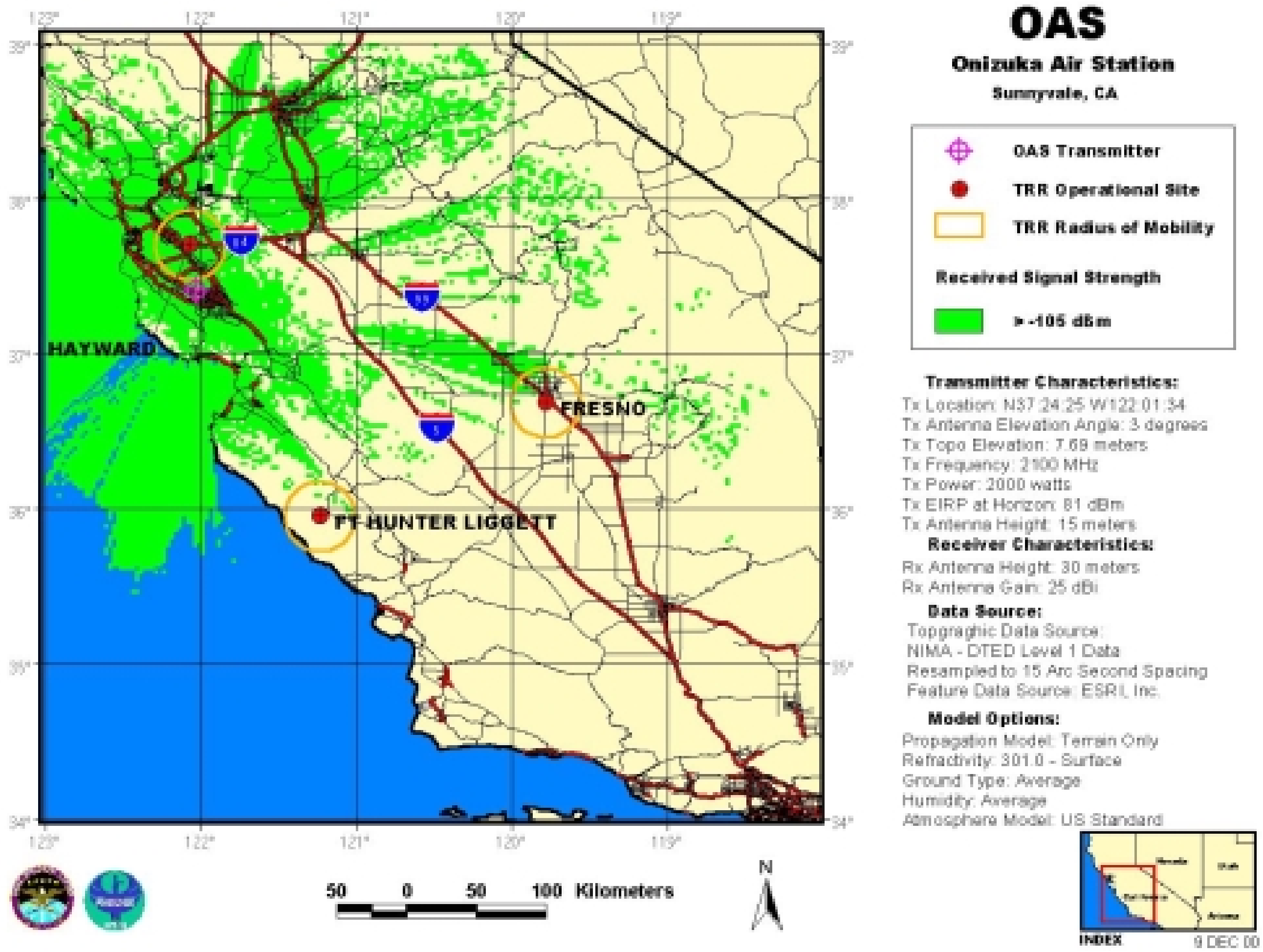

Figure C-8. Plot of OAS SGLS Interference to TRR Receivers

The analysis of the SGLS uplink interference to the TRR was based on the maximum transmit power and a 3-degree elevation angle for the antenna at each SGLS site. This situation represented the worst case interference from the SGLS transmitter to the TRR receiver. The TRR sites within the green interference areas have a potential to receive interference during some SGLS operations for co-channel frequency assignments. The SGLS also uses transportable terminals, which can operate, at any location in the US to provide additional coverage during launches, early orbit operations, anomaly resolution, and critical orbit insertion maneuvers. The parameters of the transportable SGLS terminals are similar to the parameters of the fixed SGLS systems and comparable interference contours would be generated about the temporary SGLS location. The distance separation requirements between the transportable SGLS (with the parameters of the EVCF earth terminal) and the TRR would vary between 216 km and 59 km depending on the orientation of the SGLS and TRR antennas as provided in Table C-16.

Table C-16. Interference Calculations for SGLS Transmitter to Tactical Radio Relay Receiver

2025-2110 MHz

Interference Path		Source Transmitter Data			Victim Receiver Data			FDR	Path Loss	Distance
Source	Victim	TX Power	TX Antenna	TX Cable	Inter Threshold	RX Antenna	RX Cable****			SEM
		dBm	dBi	dB	dBm	dBi	dB	dB	dB	Km
SGLS*	GRC-245 MB	63.5	12	0	-105	23	4	0	199.5	134
SGLS*	GRC-245 SL	63.5	12	0	-105	2	4	0	178.5	59
SGLS**	GRC-245 SL	63.5	16	0	-105	2	4	0	182.5	63
SGLS***	GRC-245 MB	63.5	23	0	-105	23	4	0	210.5	216

*SGLS antenna diameter is 7 m, antenna height is 10 m, antenna gain is 12 dBi for a 10 degree antenna elevation angle

**SGLS antenna gain is 16 dBi for a 5 degree antenna elevation angle

***SGLS antenna gain is 23 dBi for a 3 degree antenna elevation angle

**** Cable loss from J/F 12 for GRC-245

Coordination between SGLS and TRR frequency managers could allow some frequencies to become available for the TRR within the contour regions. However, TRR frequency usage in this band would be subjected to positive control requiring possible shut down during SGLS emergencies. This level of control would be difficult to accomplish during large-scale exercises.

C.6.1.1.3 Space Research

The 2025-2110 MHz band is also used for earth-to-space transmissions by other government space research earth stations at Corpus Christi, TX; Fairbanks, AK; Goldstone, CA; Greenbelt, MD; Kauai, HI; Merritt Is., FL; Roseman, NC and Wallops Is., MD. The Geostationary Operational Environmental Satellite (GOES) earth stations uses the 2025-2035 MHz band at Wallops Is. for tracking, telemetry and telecommand. The distance separation requirements between the GOES earth terminal (parameters obtained from reference 2) and the TRR is provided in Table C-17.

Table C-17. Interference Calculations for GOES Transmitter to Tactical Radio Relay Receiver

2025-2035 MHz

Interference Path		Source Transmitter Data			Victim Receiver Data			FDR	Path Loss	Distance
Source	Victim	TX Power	TX Antenna	TX Cable	Inter Threshold	RX Antenna	RX Cable***			SEM
		dBm	dBi	dB	dBm	dBi	dB	dB	dB	Km
GOES*	GRC-245 MB	51	14	0	-105	23	4	0	189	83
GOES*	GRC-245 SL	51	14	0	-105	2	4	0	168	51
GOES**	GRC-245 MB	51	7	0	-105	23	4	0	182	62
GOES**	GRC-245 SL	51	7	0	-105	2	4	0	161	45
GOES BL	GRC-245 SL	51	-10	0	-105	2	4	0	144	32

*GOES antenna diameter is 16 m, antenna height is 10 m, antenna gain is 14 dBi for a 5 degree antenna elevation angle

**GOES antenna gain is 7 dBi for a 10 degree antenna elevation angle

*** Cable loss from J/F 12 for GRC-245

C.6.1.2 2025-2110 MHz Band Assessment

The TRR systems do not have spectrum available to operate in the 2025-2110 MHz band. The 2025-2110 MHz band must be allocated for Government fixed and mobile operations to allow the TRR access to the band. In addition, the TRR can not share the band with the ENG because of the large number of ENG systems and the large distance separation required for compatible operations. If the ENG were moved to a different frequency band, the TRR would have access to most of the band at sites that were 216 km from SGLS sites and 83 km from space research earth-terminal sites.

C.6.1.3 2200-2290 MHz Band

The 2200-2290 MHz band is a government band and the DoD is the principal user. The band is allocated to government fixed and mobile services on a primary basis, constrained to LOS systems only, and to space research, space operations, and earth exploration satellite (EES), also on a primary basis, specified for satellite-to-earth and satellite-to-satellite paths. The SGLS functions in the band include tracking launch and space vehicles, telemetry from both launch and space vehicles, and command operations. The SGLS downlink in the band provides tracking return signal and telemetry functions. This band is used for the downlink of the NASA Tracking and Data Relay Satellite with more than 15 frequencies used at White Sands Missile Range (WSMR), Greenbelt, MD, and Merritt Is., FL. Critical guided missile (weapons) telemetry is also included in the band.

C.6.1.3.1 SGLS Downlink

The downlink associated with the 2025-2110 MHz and 1760-1840 MHz SGLS uplinks operates in the 2200-2290 MHz band. The SGLS downlink supports transponded range code, range rate determination, space vehicle State of Health (SOH) and mission data. The SGLS locations analyzed are the same as for the uplink analysis, the New Hampshire Station (NHS), the Colorado Tracking Station (CTS), the Eastern Vehicle Checkout Facility (EVCF) and the Onizuka Air Station (OAS). The data on the SGLS receiver is provided in Table C-18.[3]

[3] Space and Missile Systems Center, Standardized Interface Specification between AF Satellite Control Network Common User Element and Comm/range Segment and Space Vehicle, AFSCN SIS-000502A, El Segundo, CA: AFSCN, 22 October 1997.

Table C-18. SGLS Receiver Parameters

Desired Signal	Telemetry 1024 kb/s
Receiver Bandwidth (MHz)	1.0 (-3 dB)
Receiver Noise Power Density	-178 dBm/Hz
Receiver Noise	-118 dBm
Sensitivity	-108 dBm
Interference Threshold (I/N = -10 dB)	-128 dBm
Mainbeam Antenna Gain (7 m parabola)	41.5 dBi
Antenna Gain Off Boresight	23 dBi (3 deg), 16 dBi (5 deg), 12 dBi (10 deg)

The interference power from the TRR transmitter to the SGLS downlink receiver is calculated using the standard received power equation and the results are provided in Table C-19. The distance separation requirements between the TRR and the SGLS are more restrictive for the SGLS uplink to TRR interference interactions. The distance separation between TRR and SGLS to avoid interference range from 216 to 59 km in the 2025-2110 MHz band and from 132 to 49 km in the 2200-2290 MHz band. The TRR may have difficulty gaining access to spectrum in either frequency band at TRR sites such as Fort Carson which are near SGLS sites.

Table C-19. Interference Calculations For Tactical Radio Relay to SGLS Receiver

2200-2290 MHz Band

Interference Path		Source Transmitter Data			Victim Receiver Data			FDR	Path Loss	Distance
Source	Victim	TX Power	TX Antenna	TX Cable*	Inter Threshold**	RX Antenna*	RX Cable			SEM
		dBm	dBi	dB	dBm	dBi	dB	dB	dB	Km
GRC-245 MB	SGLS ***	32	25	5	-128	23	0	3	200.0	132
GRC-245 MB	SGLS****	32	25	5	-128	16	0	3	193.0	97
GRC-245 MB	SGLS*****	32	25	5	-128	12	0	3	189.0	80
GRC-245 SL	SGLS ***	32	2	5	-128	23	0	3	177.0	58
GRC-245 SL	SGLS****	32	2	5	-128	16	0	3	170.0	52
GRC-245 SL	SGLS*****	32	2	5	-128	12	0	3	166.0	49

* Cable loss from J/F 12 for GRC-245

** Desired signal at sensitivity, I/N = - 10 dB

***SGLS antenna diameter is 7 m, antenna height is 10 m, antenna gain is 23 dBi for a 3 degree antenna elevation angle

****SGLS antenna gain is 16 dBi for a 5 degree antenna elevation angle

*****SGLS antenna gain is 12 dBi for a 10 degree antenna elevation angle

C.6.1.3.2 Telemetry

Telemetry is heavily used in this band for such purposes as airborne weapons testing, aircraft flight testing, and a wide variety of experimental and research projects. The parameters of a typical telemetry link are provided in Table C-20. The airborne telemetry transmitter and the ground-based telemetry receiver were analyzed to determine the required distance separation with the TRR radios.

The results of the analyses are provided in Table C-21 for airborne telemetry interference to TRR receivers and in Table C-22 for TRR interference to ground-based telemetry receivers.

Table C-20. Parameters of a Typical Telemetry Link

Frequency range	2200-2290 MHz
Transmitter	Aydin Vector T400 Series Telemetry (J/F 12/6260)
Transmit power	20 W
Emission Bandwidth (MHz)	5.8 (-3dB), 5.9 (-20 dB), 13.0 (-60 dB)
Antenna gain (Transmit)	0 dBi
Antenna height	9144 m (Airborne)
Receiver	Microdyne 1200 MR (J/F 12/5608
Receiver bandwidth (MHz)	6.0 (-3dB), 9.0 (-20 dB), 21.0 (-60 dB)
Receiver noise figure	5 dB (Assumed)
Receiver sensitivity	-98 dBm (Receiver bandwidth not listed)
Receiver noise power	-101dBm
Interfering signal threshold	-107 dBm
Antenna gain (Receive)	28 dBi (Mainbeam), 20 dBi (Major Sidelobe)
Antenna height	5 m

Table C-21. Interference Calculations for Airborne Telemetry Transmitter to Tactical Radio Relay Receiver

2200-2290 MHz Band

Interference Path		Source Transmitter Data			Victim Receiver Data			FDR	Path Loss	Distance
Source***	Victim	TX Power dBm	TX Antenna dBi	TX Cable dB	Inter Threshold* dBm	RX Antenna dBi	RX Cable** dB	dB	dB	SEM Km
Airborne Telemetry	GRC-245 MB	43	0	0	-105	25	4.0	0	169.0	416
Airborne Telemetry	GRC-245 SL	43	0	0	-105	2	4.0	0	146.0	372

*I/N = -6 dB

** Cable loss from J/F 12 for GRC-245

***Aircraft Telemetry, J/F 12/6260, aircraft height is 9144 meters, emission 6M00F1D

Table C-22. Interference Calculations For Tactical Radio Relay to Telemetry Ground Receiver (J/F 12/5608)

2250 MHz

Interference Path		Source Transmitter Data			Victim Receiver Data			FDR	Path Loss	Distance
Source	Victim	TX Power dBm	TX Antenna dBi	TX Cable** dB	Inter Threshold*** dBm	RX Antenna* dBi	RX Cable dB	dB	dB	SEM Km
GRC-245 MB	Telemetry RX (10 MHz)	32	25	4	-107	20	0	0	180.0	55.1
GRC-245 SL	Telemetry RX (10 MHz)	32	2	4	-107	20	0	0	157.0	36.7

*Telemetry receive antenna gain is 20 dBi (major sidelobe), antenna height is 5 meters

** Cable loss from J/F 12 for GRC-245

*** 6 MHz BW, desired signal at sensitivity, I/N = - 6 dB

The airborne telemetry transmitter has the potential to interfere with TRR receivers at a range of 416 km. The telemetry equipment is used at China Lake, CA; WSMR; Yuma, AZ; Eglin AFB, FL; Utah Test Range, UT; Tonapoh, NV; Edwards AFB, CA; Barksdale AFB, AR; Nellis AFB, NV; Point Mugu, CA, and Tyndal, FL. The TRR radios are expected to have little access to the 2200-2290 MHz band within 416 km of test ranges because of the heavy use of telemetry frequencies at ranges.

C.6.1.4 2200-2290 MHz Band Assessment

The 2200-2290 MHz is a critical band for SGLS and other satellite link operations because interference can disrupt satellite control. The separation distance of 132 km is required between TRR transmitters and the satellite downlink receivers to avoid interference. The large number of satellite control frequencies and the large separation distance is expected to eliminate most frequencies from TRR use around earth terminal sites in the 2200-2290 MHz band. In addition, TRR radios are expected to have little access to the 2200-2290 MHz band within 416 km of test ranges because of potential interference from telemetry operations. The allocation of the Air Combat Training System (ACTS) to the 2200-2290 MHz band would restrict TRR operations in the band at many TRR sites. Many of the current ACTS 1755-1850 MHz sites are the same sites (or are near sites) that are protected with indefinite 1710-1755 MHz band protection under OBRA-93 to accommodate the TRR. The incompatibility between the TRR and the ACTS is expected to continue for operations in the 2200-2290 MHz band.

C.6.1.5 2500-2690 MHz Band

In the United States, the 2500-2690 MHz band is currently used by the Instructional Television Fixed Service (ITFS), Multipoint Distribution Service (MDS), and Multichannel Multipoint Distribution Service (MMDS). The terms MDS and MMDS are often used interchangeably. The ITFS provides formal classroom instruction, distance learning, and videoconference capability to educational users throughout the nation. The MDS provides a commercial video programming service in this frequency band, often using leased ITFS spectrum There are four basic service offerings by ITFS/MDS: analog video, digital video, unidirectional digital data, and bi-directional digital data.

Traditional one-way ITFS/MDS systems provide one-way multichannel video programming to users or subscribers. The main station transmitter broadcasts to multiple receive sites located within the 56.3 kilometers service area. A 125 kHz response station transmitter may be located at the receive site.

In a two-way MDS/ITFS system, a main station transmitter is used to send data using digital modulation to numerous users. Each user has at least one response station transceiver with its receive antenna oriented towards the main station and its transmit antenna oriented towards its associated hub station.

There are 2,175 ITFS licenses throughout the United States with over 70,000 locations serving as registered receive sites and MDS currently has 2,570 station licensees and conditional licensees.

The technical parameters of the ITFS/MDS one-way main station transmitter/receiver and one-way response station transmitter/receiver are provided in Table C-23 and C-24, respectively.[4]

Table C-23. ITFS/MDS One-way Main Station Transmitter and Receiver

Transmitter Spectrum	2500-2686 MHz
Emission Bandwidth	6 MHz
Power (EIRP)	2000 Watts
Modulation	Video/Audio
Receiver Spectrum	2686-2690 MHz
Receiver Bandwidth	125 kHz
Modulation	AM or FM
Antenna Gain	20 dBi (assumed)
Noise Figure	2.5 dB
Receiver Noise	- 120.5 dBm (typical –107 dBm to –127 dBm)
Interference Threshold	-126.5 dBm

Table C-24. ITFS/MDS One-way Response Station Transmitter and Receiver

Transmitter Spectrum	2686-2690 MHz
Emission Bandwidth	125 kHz
Power (EIRP)	40 Watts
Modulation	AM or FM
Receiver Spectrum	2500-2686 MHz
Receiver Bandwidth	6 MHz
Modulation	Video/Audio
Antenna Gain	20 dBi (Assumed)
Noise Figure	2.5 dB
Receiver Noise	-103.5 dBm
Interference Threshold*	-98 dBm
*Based on a 45 dB desired/undesired ratio with response station 35 miles from main station	

[4] Federal Communications Commission, *Interim Report, Spectrum Study of the 2500-2690 MHz Band*, 15 November 2000.

The interference analysis of interactions between the TRR and the ITFS/MDS one-way main station and response station is provided in Tables C-25 to C-28. The two-way ITFS/MDS system was not analyzed because the systems are still in development and interference thresholds have not been finalized for the ITFS/MDS digital modulations.

Table C-25. Interference Calculations ITFS/MDS Main Station Transmitter to AN/GRC-245

ITFS/MDS main station transmitter authorized 2500-2686 MHz with a 6 MHz signal bandwidth

Interference Path		Source Transmitter Data			Victim Receiver Data			FDR	Path Loss	Distance
Source	Victim	TX EIRP	TX Antenna*	TX Cable	Inter Threshold***	RX Antenna	RX Cable**			SEM
		dBm	dBi	dB	dBm	dBi	dB	dB	dB	Km
ITFS/MDS	GRC-245 MB	63	0	1	-105	25	5	0	187.0	97.0
ITFS/MDS	GRC-245 SL	63	0	1	-105	2	5	0	164.0	73.0

*ITFS/MDS MainStation antenna height is 90 meters

** Cable loss from J/F 12 for GRC-245

***Desired signal at sensitivity, I/N = - 6 dB

Table C-26. Interference Calculations for AN/GRC-245 to ITFS/MDS Main Station Receiver

ITFS/MDS main station receiver authorized 2686-2690 MHz with a 125 kHz signal bandwidth

Interference Path		Source Transmitter Data			Victim Receiver Data			FDR	Path Loss	Distance
Source	Victim	TX Power	TX Antenna	TX Cable**	Inter Threshold***	RX Antenna*	RX Cable			SEM
		dBm	dBi	dB	dBm	dBi	dB	dB	dB	Km
GRC-245 MB	ITFS/MDS	32	25	5	-126.5	20	1	12	185.5	94.0
GRC-245 SL	ITFS/MDS	32	2	5	-126.5	20	1	12	162.5	72.0

*ITFS/MDS MainStation antenna height is 90 meters, antenna gain assumed 20 dBi

** Cable loss from J/F 12 for GRC-245

***Based on I/N= -6dB, receiver bandwidth = 125 kHz and noise figure = 2.5 dB

Table C-27. Interference Calculations for AN/GRC-245 Transmitter to ITFS/MDS Response Station Receiver

ITFS/MDS response station receiver authorized 2500-2686 MHz with a 6 MHz signal bandwidth

Interference Path		Source Transmitter Data			Victim Receiver Data			FDR	Path Loss	Distance
Source	Victim	TX Power	TX Antenna	TX Cable**	Inter Threshold***	RX Antenna*	RX Cable			SEM
		dBm	dBi	dB	dBm	dBi	dB	dB	dB	Km
GRC-245 MB	ITFS/MDS MB	32	25	5	-98	20	1	0	169.0	50
GRC-245 SL	ITFS/MDS MB	32	2	5	-98	20	1	0	146.0	32
GRC-245 MB	ITFS/MDS SL	32	25	5	-98	2	1	0	151.0	36
GRC-245 SL	ITFS/MDS SL	32	2	5	-98	2	1	0	128.0	19

*ITFS/MDS Response Station antenna height is 10 meters, antenna gain assumed 20 dBi

** Cable loss from J/F 12 for GRC-245

***Based on S/I = 45dB, receiver bandwidth = 6 MHz

Table C-28. Interference Calculations for ITFS/MDS Response Station Transmitter to AN/GRC-245 Receiver

ITFS/MDS response station transmitter authorized 2686-2690 MHz with a 125 kHz signal bandwidth

Interference Path		Source Transmitter Data			Victim Receiver Data			FDR	Path Loss	Distance
Source	Victim	TX EIRP	TX Antenna*	TX Cable	Inter Threshold***	RX Antenna	RX Cable**			SEM
		dBm	dBi	dB	dBm	dBi	dB	dB	dB	Km
ITFS/MDS MB	GRC-245 MB	46	0	1	-105	25	5	0	170.0	51.0
ITFS/MDS MB	GRC-245 SL	46	0	1	-105	2	5	0	147.0	33.0
ITFS/MDS SL	GRC-245 MB	28	0	1	-105	25	5	0	152.0	37.0
ITFS/MDS SL	GRC-245 SL	28	0	1	-105	2	5	0	129.0	20.0

*ITFS/MDS Response Station antenna height is 10 meters
** Cable loss from J/F 12 for GRC-245
***Desired signal at sensitivity, I/N = - 6 dB

C.6.1.6 2500-2690 MHz Band Assessment

The distance separation required to avoid interference between the TRR and the ITFS/MDS main stations is 97 km. The distance separation required to avoid interference between the TRR and the ITFS/MDS response stations is 51 km. However, the response stations are distributed around the main station at a distance of up to 56.3 km. As a result, the distance separation requirement between the TRR and the ITFS/MDS main station, based on the response station interference threshold, is 107.3 km. The 2175 ITFS and 2570 MDS main stations would require a separation distance of 107.3 km for TRR in-band operations. If the band can be segmented to provide some frequencies for exclusive TRR operations, the TRR could successfully utilize that portion of the band. The band made available for military use would have to be allocated to government use on a primary basis with equivalent regulatory protection.

C.6.2 Operational Impact

The MSE AND TRI-TAC impacts under this option are virtually the same as those described under Option 2.

The impacts to amphibious and general Marine Corps battlefield training would be virtually the same as those desribed under Option 2.

C.7 Option 4 – Vacate 1755-1850 MHz

C.7.1 Technical Assessment

The elimination of the 1755-1850 MHz band at all DoD TRR sites would stop operations of TRR duplex links at all sites where the 1710-1755 MHz band is not protected indefinitely by OBRA-93.

TRR duplex frequency assignments would not be possible without access to 1710-1850 MHz frequencies because of the requirement for a minimum of 50.125 to 63.0 MHz frequency separation between transmit and receive frequencies. The only band available for TRR operations, 1350-1390 MHz, can not provide the needed frequency separation. The sites without spectrum for TRR operations would include Fort Hood and Fort Carson. Some sites have access to the 1432-1435 MHz band and one high data-rate duplex link could operate at these sites.

The 2025-2110 and 2500-2690 MHz bands have been assessed for TRR use and no spectrum was identified for the TRR. The 2200-2290 MHz band is allocated for government fixed and mobile operations, but the current users of the band must be protected. The separation distance of 132 km is required between TRR transmitters and the satellite downlink receivers to avoid interference. The large number of satellite control frequencies and the large separation distance is expected to eliminate most frequencies from TRR use around earth terminal sites in the 2200-2290 MHz band. In addition, TRR radios are expected to have little access to the 2200-2290 MHz band within 416 km of test ranges because of potential interference from telemetry operations. The 2200-2290 MHz band is being investigated for ACTS use as an alternate to the current 1755-1850 MHz band. The frequency-distance separation requirements between the ACTS and the TRR are comparable to the requirements for airborne telemetry. As a result, the 4400-4940 MHz band was assessed as an alternate frequency band for TRR operation.

2003 and 2006 Time Frame. The loss of the 1755-1850 MHz band would disrupt TRR operations at sites without access to the 1710-1755 MHz band until AN/GRC-245 type radios with an ability to operate above 2000 MHz become widely available after 2006.

2010 Time Frame. The replacement of current TRR equipment with AN/GRC-245 type radios operating above 2000 MHz could be accomplished after the 2006 time frame. The government spectrum available above 2000 MHz and the non-government 2500-2690 MHz frequency band were investigated in the previous section to see if training requirements could be met in these bands and little spectrum was identified. The 4400-4940 MHz band was investigated as a candidate for TRR.

C.7.1.1 4400-4940 MHz Band

The 4400-4940 MHz band was investigated for TRR operations; however, this study did not investigate the 4400–4940 MHz band for worldwide spectrum availability for the TRR. Migration of TRR systems that operate in the 1755-1850 MHz band to the 4400-4940 MHz band is not feasible due to the operational impacts resulting from the significant difference in technical characteristics of the bands and due to the limitations required to protect incumbent users in the 4400-4940 MHz band.

The 4400–4940 MHz band supports the operations of many fixed and transportable line-of-sight and tropospheric scatter radio relay systems, for the exchange of weapons sensor data, telemetry, and command links for weapons and range systems. The systems are generally wideband, multichannel systems and are used by all the services.

The relocation of TRR operations to the 4400 – 4940 MHz band would involve a design of a new series of radios, significant changes in operational doctrine, and manpower increases to restore essential military capabilities currently supported by operations in the 1755-1850 MHz band. Parameters of notional TRR systems are provided in Table C-29.

Table C-29. Parameters of Notional Tactical Radio Relay Systems in the 4400-5000 MHz Band

Frequency range	4400 – 5000 MHz
Transmit power	1.6 W
Emission Bandwidth (MHz)*	2.0 (-3 dB)
Antenna gain	32 dBi at 4.4 GHz
Antenna height	30 m
Receiver bandwidth (MHz)*	6.7 (-3 dB)
Interfering signal threshold*	-105 dBm
Cable losses	6 dB @ 4700 MHz

A high antenna gain is needed to compensate for the increased link losses at 4400-4940 MHz. However, the 4400–4940 MHz antenna would have a beamwidth of approximately 3.5 degrees. The narrow-beam antenna will significantly reduce the mobility and survivability of military personnel and units. In some situations, link distances would be significantly reduced thereby resulting in increased numbers of TRR systems with associated increases in manpower.

A notional TRR system (Table C-29) was evaluated for electromagnetic compatibility (EMC) with the incumbent equipment in the 4400–4940 MHz band. The incumbent equipment analyzed included the AN/TRC-170, AN/GRC-222, and the Cooperative Engagement Capability (CEC).

AN/TRC-170. The AN/TRC-170 is a transportable radio terminal providing full-duplex digital voice and data at ranges up to 330 km by means of line-of-sight or tropospheric scatter modes of propagation in the 4400–4999 MHz band. The parameters of the AN/TRC-170 used in the analysis are presented in Table C-30.

Table C-30. Parameters of the AN/TRC-170 From J/F 12/4480/4

Frequency range	4400 – 4999.9 MHz
Transmit power	2 KW
Emission Bandwidth (MHz)	5.0 (-3dB), 7.0 (-20dB), 13.0 (-60dB)
Antenna gain	40.5 dBi (mainbeam)
Antenna height	5 m
Receiver bandwidth (MHz)	4.0 (-3dB), 6.0 (-20dB), 10.0 (-60dB)
Receiver noise figure	5 dB (estimate)
Receiver sensitivity	NA
Receiver noise power	-103 dBm
Interfering signal threshold	-109 dBm
Cable losses	NA
Waveform	7M00M7D

The AN/TRC-170 has the greatest number of frequency assignments in the band and there are three versions currently in use. The AN/TRC-170(V2) version has typical parameters based on a review of the frequency assignment data files and this version was used in the analysis. The AN/TRC-170 provides high capacity backbone communications in tactical, strategic and administrative environments and operates in close proximity to the MSE, TRI-TAC, and DWTS systems. The distance separation required to eliminate interference between the AN/TRC-170 and a notional TRR system was calculated using the standard interference equation and the results are provided in Figures C-9 and C-10.

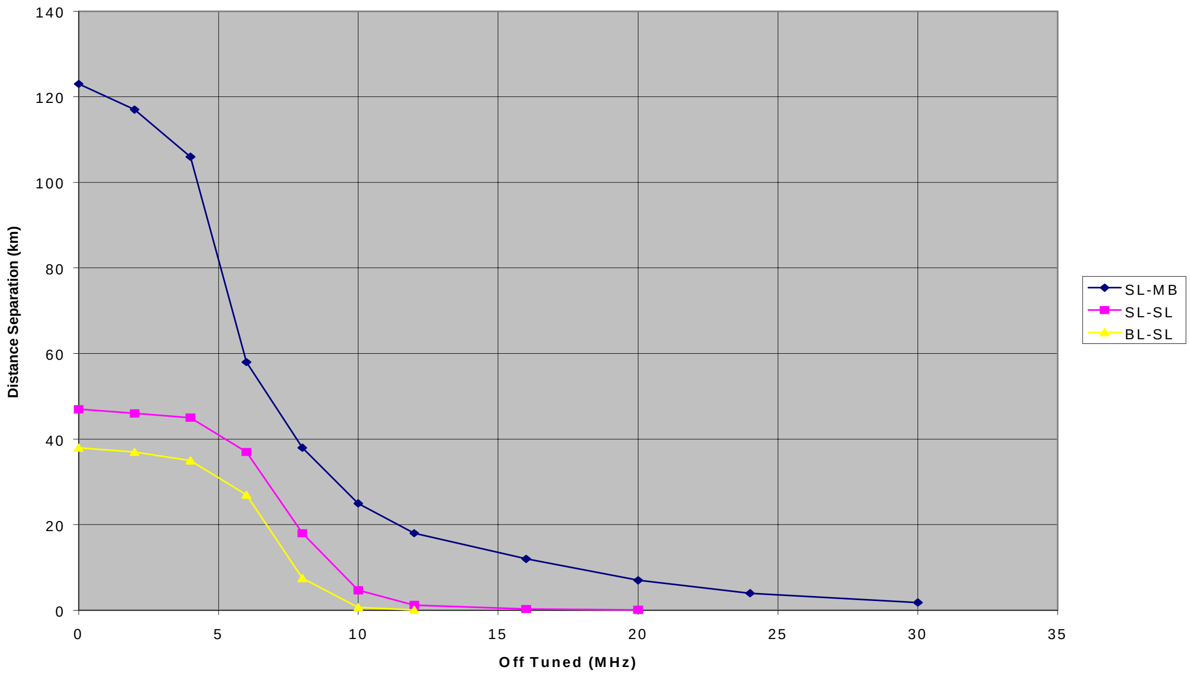

Figure C-9. Frequency-Distance Separation for AN/TRC-170 to a TRR

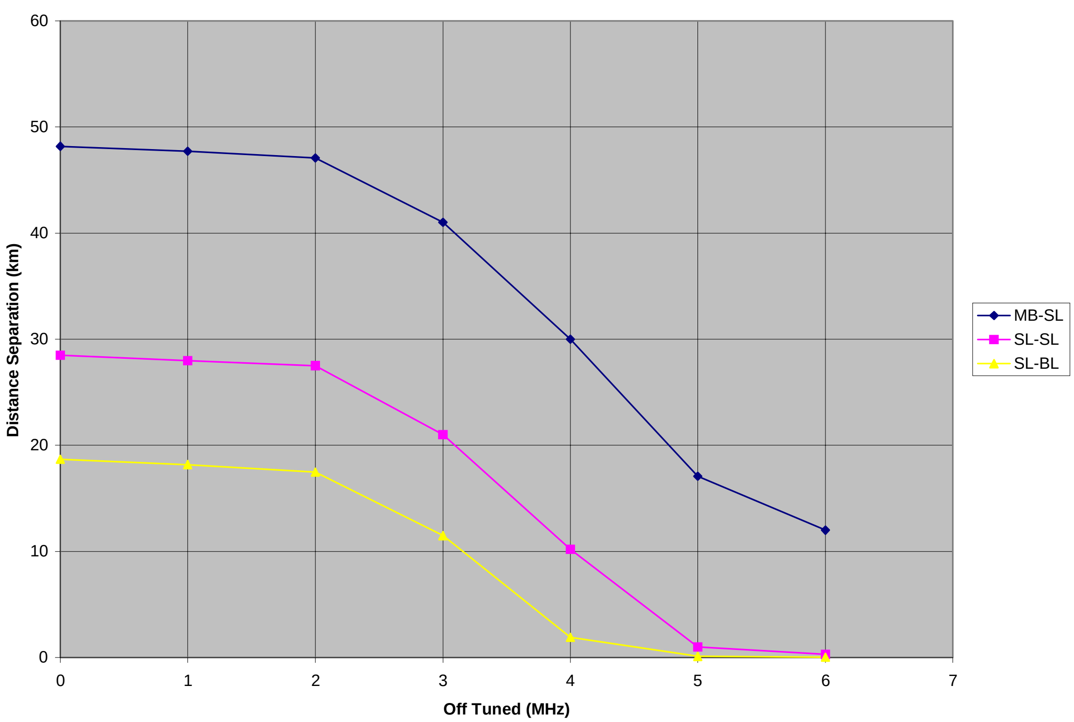

Figure C-10. Frequency-Distance Separation for a TRR to AN/TRC-170

The frequency separation requirements for AN/TRC-170 transmitters and TRR receivers are in the range of 12 to 18 MHz for co-located radios (distance separations of approximately 200 meters) with sidelobe or backlobe antenna orientations. The frequency-distance separation requirements for the AN/TRC-170 high power mode are larger (by a factor of two or three) than the separation requirements for LOS microwave radios and additional spectrum will be required to provide compatible frequency assignments.

AN/GRC-222. The AN/GRC-222 is a high traffic digital radio that operates in a LOS mode of propagation. The AN/GRC-222 has a capacity to 18.72 mbps of data using 8-level phase shift keying (PSK) modulation. The radio parameters of the AN/GRC-222 are provided in Table C-31, and the results of the analysis are provided in Figures C-11 and C-12. The collocated frequency-separation requirement between the AN/GRC-222 and a TRR receiver is approximately 8 MHz.

Table C-31. Parameters of the AN/GRC-222 J/F 12/6204

Frequency range	4400 – 5000 MHz
Transmit power	0.8 W
Emission Bandwidth (MHz)*	5.8 (-3dB), 7.6 (-20dB), 12.2 (-60dB)
Antenna gain	33 dBi (mainbeam)
Antenna height	30 m
Receiver bandwidth (MHz)*	12.0 (-3dB), 19.0 (-20dB), 46.0 (-60dB)
Receiver noise figure	7 dB (assumed)
Receiver sensitivity*	-66 dBm @ 18720 Kb/s and BER = 10E-5
Receiver noise power*	-91 dBm (assumed)
Interfering signal threshold*	-97 dBm (assumed)
Cable losses	6 dB @ 4700 MHz (assumed)
Waveform	7M00G2D, 8 PSK
*18720 kb/s	

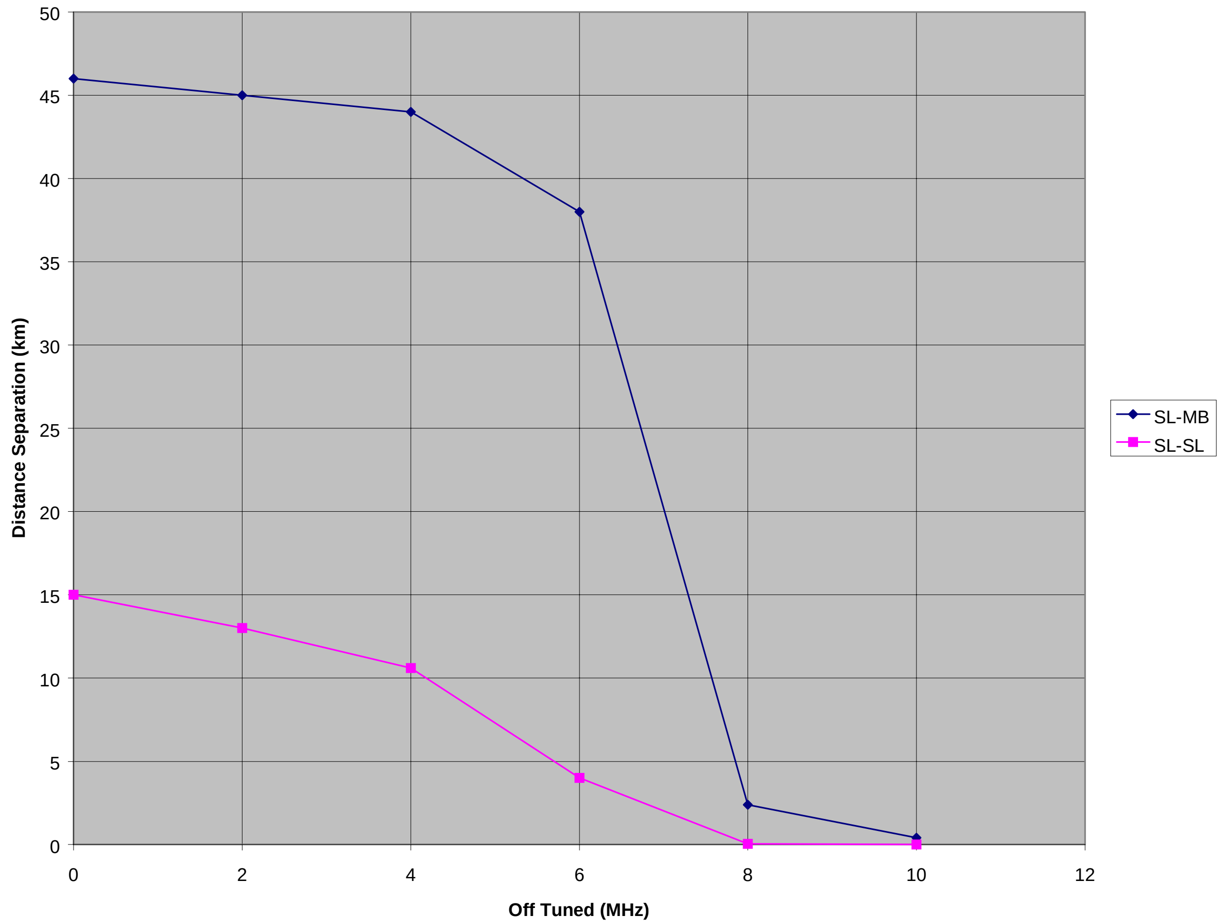

Figure C-11. Frequency-Distance Separation for AN/GRC-222 to a TRR

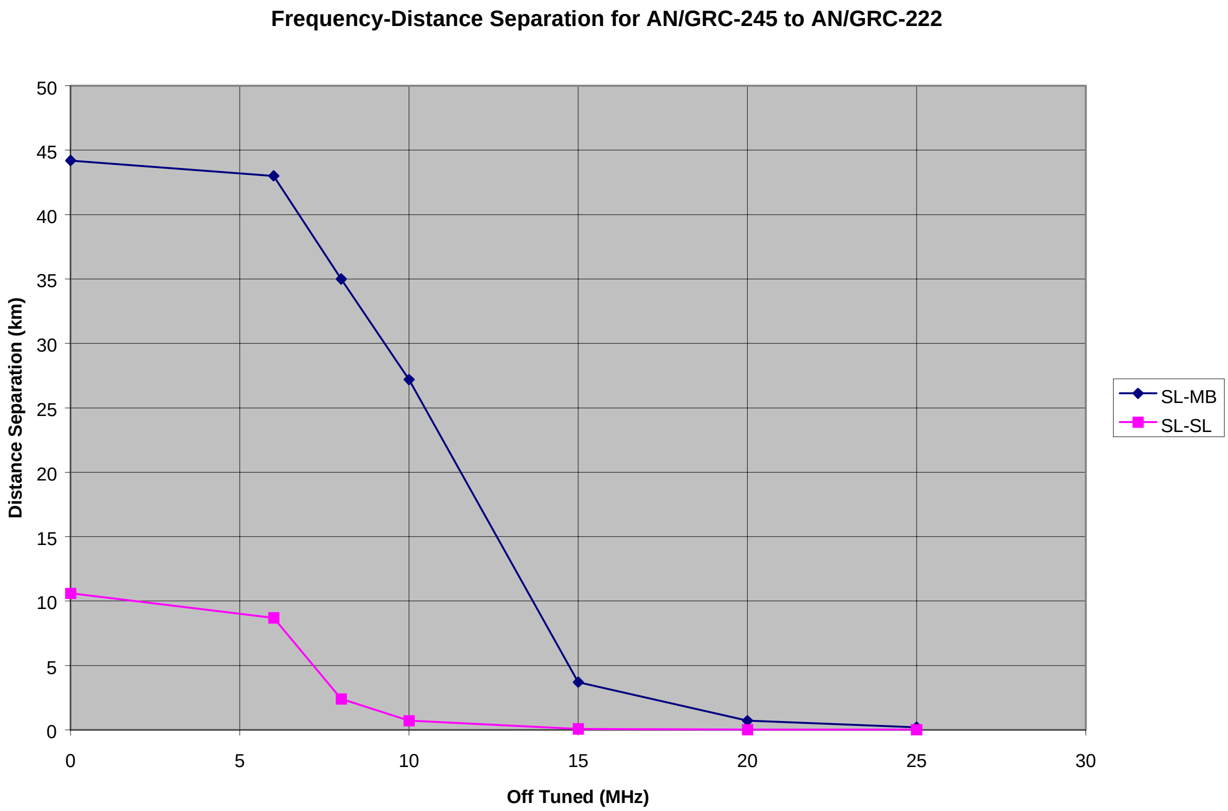

Figure C-12. Frequency-Distance Separation for a TRR to AN/GRC-222

Cooperative Engagement Capability (CEC). CEC is a system that provides the means to conduct coordinated Anti-Air Warfare (AAW) area defense. All Cooperating Units (CU) that participate in a CEC network exchange sensor data in near real time to form an identical composite track and identification air surveillance picture on each CU. This sensor cooperation function allows targets to be detected and compositely tracked that a single individual sensor could not track. The composite air picture provides the means for a battle force to accomplish optimized weapon system assignments and the coordinated engagements of threats. CEC is implemented via a Cooperative Engagement Processor (CEP) and a Data Distribution System (DDS). The CEP is a computer system responsible for forming the composite track and identification data base, and for coordinating engagements. The DDS is an radio frequency (RF) network responsible for the secure, environmentally resistant transfer of sensor and weapon data among the CUs. CEC is currently being deployed aboard Navy E-2C aircraft and the major Navy surface combatants, carriers, and amphibious class ships. CEC is also now in development for deployment with the USA PATRIOT, USAF AWACS, and USMC AN/SPS-59 radar systems. The parameters for CEC are provided in Table C-32.[5]

Table C-32. Parameters of the Cooperative Engagement Capability (CEC) from FCC-00-63

Frequency	4929 MHz and Below
Emission Bandwidth	22 MHz
Maximum Transmit Power (EIRP)	630 kW
Out-of-Band Emissions	+/- 7.65 MHz (-3 dBc), +/- 12.1 MHz (-30 dBc)
Transmitter Noise	+/- 25.6 MHz Less Than –145 dBc/Hz

The analysis of CEC interference to a relocated TRR concluded that band sharing and band segmentation are not feasible. For band sharing, the separation distance required to reduce CEC in-band signals to a maximum allowed interference level was determined to be beyond the RF horizon, which could exceed 200 NM for airborne CEC platforms. Since both TRR and CEC may operate in close proximity, that separation distance is not acceptable. For band segmentation, the distance may reduce to 30 nmi (55 km), which is again unacceptable. Most significant, for band segmentation, CEC may have to incur a 250 MHz reduction in usable spectrum. That spectrum reduction would have significant and unacceptable impacts on CEC combat readiness and operation.

C.7.1.2 4400-4940 MHz Band Assessment

Battle Space management doctrine and tactics will require collocation of CEC and TRR aboard Navy ships and ashore elements of Marine and Army Air Defense radars and Missile Batteries, among other things. However, relocation of TRR systems from the 1755-1850 MHz band into the 4400-4940 band would preclude simultaneous use of CEC and TRR during, among other things, carrier battle group operations, amphibious operations, and joint operations ashore. It is contrary to battle space management doctrine and tactics to forgo the simultaneous use of critical warfighting systems. Trade-offs between use of anti-air warfare systems (like CEC) and systems for the exchange of tactical data (TRR) are unacceptable.

If AN/TRC-170 systems and the TRR systems both operate in this same frequency band, additional spectrum would be required to provide larger guardbands around the AN/TRC-170 emissions. An additional spectrum requirement of 50 MHz would be necessary to provide the guardband with CEC.

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[5] Federal Communications Commission, *FCC Proposes Licensing and Service Rules for the 4.9 GHz Spectrum Band*, NPRM FCC-00-63, 29 February 2000.

Accommodating the TRR in the 4400-4940 MHz band could require a 200 to 250 MHz reduction in CEC spectrum and have a significant impact on CEC combat readiness and operations. The major operational impact of a decrease in RF spectrum is a decrease in the number of CUs that can simultaneously participate in a CEC network. Each CU increases the warfighting effectiveness of the battle force by providing: (1) sensors that uniquely contribute to the formation and update of a composite track and identification data base, and/or (2) weapon systems that uniquely contribute to target engagement based on that composite data base. The decrease in bandwidth, then, degrades the overall warfighting capabilities of a CEC network, the individual combatants that comprise the network, and the individual combatants that must be purposely omitted from the network.

C.7.2 Operational Impact

Vacating the entire 1755-1850 MHz band is not an option for the Army. This band is a key element of Army battlefield communication networks for the foreseeable future, including the new HCLOS radio. Alternate frequency bands above the mid 2 GHz area may not be suitable for tactical microwave systems. The 1700 MHz band is used for mobile communications because the propagation characteristics allow for better penetration of foliage, use of inexpensive coaxial cables instead of expensive wave guides, and have a wide beam width allowing for quicker path alignment. These characteristics are critical to tactical mobile communications units because of their mission to provide the Army with the ability to relocate command centers quickly. Moving the communications network to a higher frequency band would negate many of these factors, thus decreasing the operational utility of the system. Otherwise, over the air training exercises would be severely restricted at most of the training locations available to the Army. The operational implications from the inability to train in the US would directly impact combat operations. Deployment and maintenance of the ACUS/MSE system during a crisis and network management of large brigade/division/corps level units will be degraded because of the lack of trained operators.

Vacating the entire 1755-1850 MHz band is unacceptable for the Marine Corps until new frequency space is identified and a new system is developed. No existing materiel solutions are available for fielding until at least the 2010 time frame. Operational impacts are worse than Option 1, as no capability would remain for amphibious and battlefield training.